PB84-120633

Nationwide Urban Runoff Program, the Long Island Segment, Long Island Regional Planning Board, Hauppauge, New York

Long Island Regional Planning Board
Hauppauge NY

Dec 82

U.S. Department of Commerce
National Technical Information Service
NTIS

THE LONG ISLAND SEGMENT
OF THE
NATIONWIDE URBAN RUNOFF PROGRAM

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No. PB84 120633
4. Title and Subtitle: Nationwide Urban Runoff Program, the Long Island Segment, Long Island Regional Planning Board, Hauppauge, New York - Final Report.			5. Report Date: December, 1982
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: LONG ISLAND REGIONAL PLANNING BOARD H. Lee Dennison County Office Building Veterans Memorial Highway Hauppauge, Long Island, New York 11787			10. Project/Task/Work Unit No. P002213-01-0 11. Contract(C) or Grant(G) No. (C) (G) P002213-01-0
12. Sponsoring Organization Name and Address: EPA, Office of Water Program Operations Water Planning Division 401 M Street, SW Washington, D C 20460			13. Type of Report & Period Covered: Final 14.

15. Supplementary Notes

The report gives an

16. Abstract (Limit: 200 words)

Evaluation of recharge basins with respect to pollution of the groundwater aquifer, and investigations focused on the feasibility of and various techniques for achieving improvements in water quality, thus allowing re-opening of areas currently closed to shellfishing.

17. Document Analysis a. Descriptors

Hydrology
Urban development
Watersheds
Water pollution
Water resources
Sedimentation
Storms
Regional planning
Urban planning
Civil Engineering

b. Identifiers/Open-Ended Terms

Runoff
Streamflow
Stream pollution
Rainfall
Snowmelt
Soil Erosion
Water Quality
Sediments
Sediment Transport
Suspended Solids
Storm Drains
Urbanization
Land use

c. COSATI Field/Group

REPRODUCED BY
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

18. Availability Statement: No restriction on distribution. Available from National Technical Information Service, Springfield, VA 22161	19. Security Class (This Report): UNCLASSIFIED	21. No. of Pages: 265
	20. Security Class (This Page): UNCLASSIFIED	22. Price

THE LONG ISLAND SEGMENT OF THE NATIONWIDE URBAN RUNOFF PROGRAM

LEE E. KOPPELMAN
Project Director

EDITH TANENBAUM
Deputy Project Director

December 1982

LONG ISLAND REGIONAL PLANNING BOARD

Hauppauge, New York

This document was prepared by the Long Island Regional Planning Board pursuant to Section 208, Federal Water Pollution Control Act Amendments of 1972 (PL 92–500). This project has been financed in part with Federal funds from the United States Environmental Protection Agency under Grant Number P002213–01–0. The contents do not necessarily reflect the views and policies of the United States Environmental Protection Agency, nor any state, county, regional or local agency participating in the 208 program.

Library of Congress Catalog Card Number: 83-81336

LONG ISLAND REGIONAL PLANNING BOARD

James Shuart
Chairman

John J. Hart
Vice Chairman

Patrick F. Caputo
John V.N. Klein
John Wickham
John W. Wydler

Lee E. Koppelman
Executive Director

NASSAU COUNTY

SUFFOLK COUNTY

Ex Officio

Ludwig Hasl
Commissioner
Department of Public Works

A. Barton Cass
Commissioner
Department of Public Works

Peter T. King
Comptroller

Joseph Caputo
Comptroller

Advisory

Honorable Francis T. Purcell
County Executive

Honorable Peter F. Cohalan
County Executive

Honorable Thomas S. Gulotta
Vice Chairman
County Board of Supervisors

Honorable Louis Howard
Presiding Officer
County Legislature

Honorary

Leonard W. Hall

H. Lee Dennison

County Coordination

Herbert Libert

Arthur Kunz

Technical Advisory Committee Voting Members

Lee E. Koppelman
Project Director
Long Island Regional Planning Board

Edith G. Tanenbaum
Deputy Project Director

Theodore Burger*
Nassau County Department of Health

Donald Lister**
Nassau County Department of Planning

John D. Murray
Massau County Department of Public Works

Aldo Andreoli
Suffolk County Department of Health Services

Vito Minei
Suffolk County Department of Health Services

August A. Guerrera
Suffolk County Water Authority

**replaced Thomas Maher 4/1/80*
***replaced Irwin Kessman 10/27/80*

Advisory Members

Philip Barbato
New York State Department of Environmental Conservation

George Neimeth
New York State Department of Transportation

Thomas Doheny**
Town of Hempstead

Jeremy Barth
Town of Oyster Bay

Dennis Lynch
Town of Babylon

Stuart Buckner
Town of Islip

Sarah Meyland
New York State Commission on the Water Resource Needs of Long Island

Nancy Papoulias*
United States Environmental Protection Agency

Henry F.H. Ku
United States Geological Survey

Kevin Quinn
Town of North Hempstead

Michael White***
Town of Huntington

James McClave
Town of Smithtown

Thomas Cramer****
Town of Brookhaven

George Prios*****
New York State Commission on the Water Resource Needs of Long Island

**replaced John Ulshoefer*
***replaced Harold Udell*
****replaced Malcolm Hair*
*****replaced George Prios*
******replaced Edward Cantor*

Principal Study Participants

Nassau County Department of Health
Theodore B. Burger
Robert Stegemann
Bruce F. Mackay
Richard H. Altieri

Suffolk County Department of Health Services
Vito Minei
Robert Farmer
Steven Cary

Nassau County Department of Public Works
John D. Murray

Suffolk County Water Authority
August A. Guerrera

U.S. Geological Survey
Henry F.H. Ku
Dale L. Simmons
Gail E. Mallard

Additional Study Participants

Nassau County Department of Health
John J. Dowling, M.D.
Francis V. Padar
James Adamski
John Oeckler
Donald L. Scanlon
George P. Gaige
Cheryl Strober
Carol Sudol
Delia Riccardi
Patrick Barragan
Paul Pugliani
William Vannostrand, Jr.
William St. John

Suffolk County Department of Health Services
David Harris, M.D.
Herbert W. Davids
Aldo Andreoli
Robert Edlind
Lawrence Weisberg
Edward Olson
Lawrence Stipp
Eric Joungblood
Ronald Green
Thomas Keenan
Karl Vogel
Raja Kavasery
Natalie Frazer
Leslie S. Trent

U.S. Geological Survey
Donald L. Bingham
Irwin H. Kantrowitz
David A. Aronson
Elizabeth A. Montano

LONG ISLAND 208 CITIZEN ADVISORY COMMITTEE

Edward C. Stephan, USN (ret)
Chairman

David Newton
Vice Chairman

Rev. Jack Alford (V)
Anthony Alba
Lorne Birch (V)
John Black (V)
Anthony Cuzzucoli (A)
Esther Ernst (A)
John Finkenberg (V)
Adelaide Flatau (V)
Elsa Ford
Jane S. Gombieski
Louise Haberman
James Heatly (V)
Evelyn Huth
Thomas Junor (V)
Julian Kane (V)

Rev Dedra Kimensky (V)
Rodney Leuthardt (V)
Diane Lundegaard (A)
Nancy Manfredonia
Arthur Mittelstaedt (V)
Joan Northam (A)
Robert Reid (V)
Maurie Semel (V)
Joy Squires (V)
Morton Strassberg (V)
John White (A)
George Wilde (A)
Fred Woolf (A)
Jean Wood (A)

V = Voting Member
A = Alternate

Consultant

Lawler, Matusky and Skelly, Engineers
and Fanning and Phillips

Administration and Report Preparation

Randall S. Davis
DeWitt Davies
James Finkle
Lauretta Fischer Key
Arthur Kunz
Mark Riegner
Sy Robbins
Ann Sielman
Carolee Swick
Edith Tanenbaum
Carol Moor Walsh
Israel Wilenitz

Clerical Staff

Gail Calfa
Paula Davantzis
Kerri Grattan
Barbara Horoski
Edith Jones
Theresa Kinkead
Penny Kohler
Eileen Retzger
Edith Sherman
Jeanne Widmayer

Accounting

Lucille Gardella

Cartographic and Publication

Anthony Tucci

Louis Brida
Thomas Frisenda
Carl Lind

Typography

Info Scan, Inc.

Acknowledgements

This program—a continuation of the Board's earlier efforts in developing the Long Island Comprehensive Waste Treatment Management Plan—has also been a collective endeavor, in the best sense of that term. Interdisciplinary skills, involving a wide array of scientific talents from all levels of government, were required. The program could not have been satisfactorily completed without the enthusiastic participation and support of scores of people. Their dedication and commitment accounts for this product. The simple listing of participants in no way acknowledges their invaluable contributions to the people of Nassau and Suffolk Counties. The most we can do, however, is to express a sense of deep appreciation and respect for the high caliber of professionalism shown by representatives from the various County Departments, the United States Environmental Protection Agency, the New York State Department of Environmental Conservation, and the United States Geological Survey.

We would especially like to thank Mr. Eugene Driscoll, who in his capacity as consultant to the Environmental Protection Agency for the Nationwide Urban Runoff Program, furnished expertise and counsel to us throughout the course of the program.

Mr. Ernest Cobb, and later, Mr. Stuart Tuller of the United States Environmental Protection Agency, Water Planning Division, did much to provide effective liason between Washington and the Long Island program.

The sampling operations and control measure applications could not have been successfully carried out without support from the New York State Department of Transportation, which allowed access to two of its recharge basins. In addition, we wish to thank Mr. Ronald Shields, Operations Manager of Pembrook Management, Inc., who allowed the U.S. Geological Survey to place instruments at the Walt Whitman Shopping Center recharge basin. The Village of Bayville and the Town of Oyster Bay permitted the Nassau County Department of Health to install an automatic rain gage at the municipal building and at a park building, respectively. Mr. Robert Hanington, the Town of Babylon Superintendent of Highways, arranged for his Department to undertake a once a week sweeping of the Central Avenue, Deer Park study area over an eight month period.

We also wish to note the valued input provided by personnel of the Nassau County Department of Public Works, who were responsible for building the solid bottom catch basin at Perry Avenue, Bayville, and the box culvert at Unqua Pond, Massapequa, thus facilitating samplin at those sites. Personnel of the Nassau County Department of General Services also assisted in constructing the work platform that was installed in one of the Perry Avenue leaching pool structures.

Although we have made a sincere effort to name the many participants, there is always the possibility of omission through error on our part. We, therefore, wish to publicly thank all of the program participants.

In particular, the services of Dr. Edith Tanenbaum, who served as Deputy Project Director, must be applauded. Her dedication to the project went well beyond the normal expectations of professional service. To the extent that this document is clear, concise, and readable to an audience beyond those immediately concerned, it is a testimony to her skills and commitment.

LOCATION MAP

KEY TO MUNICIPALITIES IN NASSAU AND SUFFOLK COUNTIES

VILLAGES IN NASSAU COUNTY

Town of Hempstead

1. Atlantic Beach
2. Bellerose
3. Cedarhurst
4. East Rockaway
* 5. Floral Park (North Hempstead)
6. Freeport
7. Garden City
8. Hempstead
9. Hewlett Bay Park
10. Hewlett Harbor
11. Hewlett Neck
12. Island Park
13. Lawrence
14. Lynbrook
15. Malverne
16. Rockville Centre
17. South Floral Park
18. Stewart Manor
19. Valley Stream
20. Woodsburgh

Town of Oyster Bay

21. Bayville
22. Brookville
23. Centre Island
24. Cove Neck
25. Farmingdale
26. Lattingtown
27. Laurel Hollow
28. Massapequa Park
29. Matinecock
30. Mill Neck
31. Muttontown
32. Old Brookville
33. Oyster Bay Cove
34. Sea Cliff
35. Upper Brookville

Town of North Hempstead

36. Baxter Estates
*37. East Hills (Oyster Bay)
38. East Williston
39. Flower Hill
40. Great Neck
41. Great Neck Estates
42. Great Neck Plaza
43. Kensington
44. Kings Point
45. Lake Success
46. Manorhaven
47. Mineola
48. Munsey Park
*49. New Hyde Park (Hempstead)
50. North Hills
*51. Old Westbury (Oyster Bay)
52. Plandome
53. Plandome Heights
54. Plandome Manor
55. Port Washington North
56. Roslyn
57. Roslyn Estates
*58. Roslyn Harbor (Oyster Bay)
59. Russell Gardens
60. Saddle Rock
61. Sands Point
62. Thomaston
63. Westbury
64. Williston Park

CITIES IN NASSAU COUNTY

65. City of Glen Cove
66. City of Long Beach

VILLAGES IN SUFFOLK COUNTY

Town of Huntington

67. Asharoken
68. Huntington Bay
69. Lloyd Harbor
70. Northport

Town of Babylon

71. Amityville
72. Babylon
73. Lindenhurst

Town of Smithtown

74. Head of the Harbor
75. Nissequogue
76. Village of the Branch

Town of Islip

77. Brightwaters
78. Ocean Beach
79. Saltaire

Town of Brookhaven

80. Bellz Terra
81. Bellport
82. Lake Grove
83. Old Field
84. Patchogue
85. Poquott
86. Port Jefferson
87. Shoreham

Town of Southampton

88. North Haven
89. Quogue
*90. Sag Harbor (East Hampton)
91. Southampton
92. Westhampton Beach

Town of Southold

93. Greenport

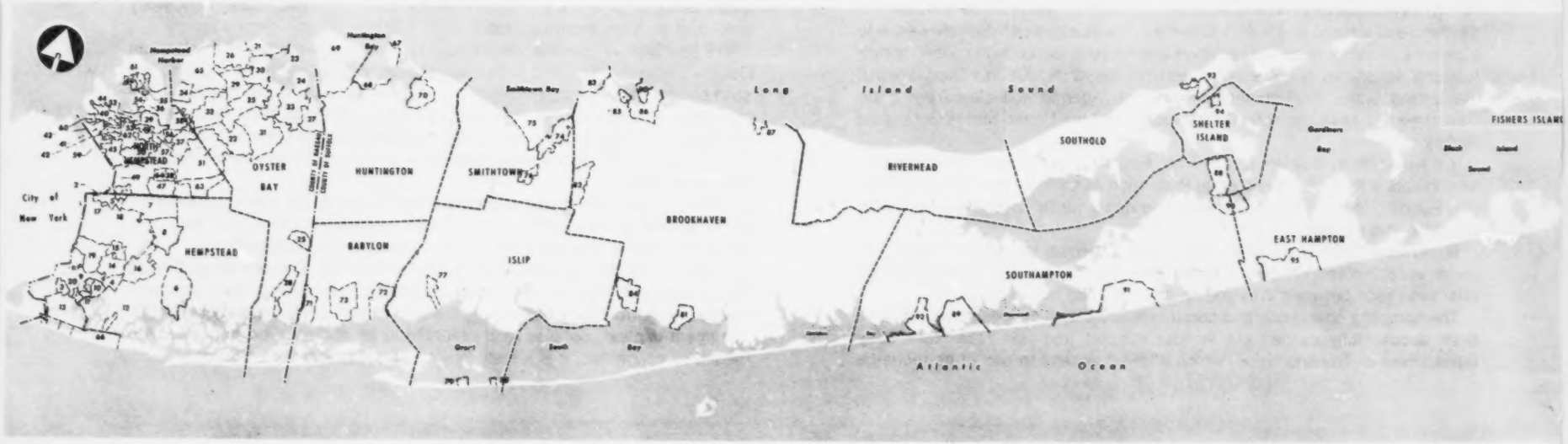
Town of Shelter Island

94. Dering Harbor

Town of East Hampton

95. East Hampton

*Incorporated Villages situated within two towns



Nassau and Suffolk Counties–Municipal Boundaries

TABLE OF CONTENTS

Section

Page

1 Introduction

1.0 The Nationwide Urban Runoff Program 1

1.1 Relation of the Nationwide Urban Runoff Program to Long Island 2

1.2 Description of the Area 2

1.3 Water Quality Planning on Long Island 2

1.4 Problems Selected for Study: The Long Island Contribution to the National Effort 3

1.5 The Work Plan 3

1.6 Report Description 4

1.7 References Cited 5

2 The Groundwater Component 7

2.0 Introduction 7

2.1 Description of Monitoring Sites 8

2.1.1 Centereach 8

2.1.2 Huntington 15

2.1.3 Laurel Hollow 15

2.1.4 Plainview 15

2.1.5 Syosset 15

2.2 Sampling Program 15

2.2.1 Equipment 15

TABLE OF CONTENTS (Cont'd)

Section — Page

2.2.2 Collection Procedures . . . 15
2.2.3 Data Storage . . . 17
2.3 Characteristics of Sampled Storms . . . 18
2.4 Analytical Procedures . . . 21
2.4.1 Standard Chemical Analysis . . . 21
2.4.2 Bacteria . . . 21
2.4.3 Priority Pollutants . . . 21
2.5 Analysis of Data . . . 21
2.5.1 Runoff/Precipitation Relationship . . . 21
2.5.2 Stormwater Quality . . . 24
2.5.2.1 Standard Chemical Analysis . . . 24
2.5.2.2 Priority Pollutants . . . 24
2.5.2.3 Bacteria in Stormwater and Groundwater . . . 37
2.5.2.4 Basin Soil . . . 39
2.6 References Cited . . . 43

3 The Surface Water Component, Detailed Study Areas in Nassau and Western Suffolk . . . 45
3.0 Introduction . . . 45
3.1 Perry Avenue, Bayville Site . . . 45
3.1.1 Site Description . . . 45
3.1.2 Sampling Program . . . 48
3.1.2.1 Equipment . . . 49
3.1.2.2 Sampling Procedures . . . 49
3.1.3 Characteristics of Sampled Storms . . . 51
3.1.4 Analysis of Data . . . 52
3.1.4.1 Description of In-Line Storage Leaching Drainage System . . . 52
3.1.4.2 Load Reduction Analysis . . . 52
3.1.4.3 Control Measure Effectiveness . . . 56

TABLE OF CONTENTS (Cont'd)

Section

Page

3.2 Unqua Pond, Massapequa Site 58
3.2.1 Site Description 58
3.2.2 Sampling Program 60
3.2.2.1 Equipment 60
3.2.2.2 Sampling Procedures 60
3.2.3 Description of Impoundment as a Control Measure 60
3.2.4 Characteristic of Sampled Storms 61
3.2.5 Analysis of Data 62
3.2.5.1 Relationship of Runoff to Precipitation 62
3.2.5.2 Bacteriological Parameters 63
3.2.5.3 Chemical Parameters 63
3.2.6 Control Measure Evaluation 65
3.2.6.1 Load Reduction Analysis 65
3.2.6.2 Waterfowl Impact Upon Pond Water Quality 68
3.2.6.3 Prediction of Bacteriological Reductions of Runoff in Ponds 70
3.3 Central Avenue (Carlls River) Deer Park Site 72
3.3.1 Site Description 72
3.3.2 Sampling Program 74
3.3.2.1 Equipment 74
3.3.2.2 Sampling Procedures 74
3.3.3 Characteristics of Sampled Storms 75
3.3.4 Analysis of Data 75
3.3.4.1 Relationship of Runoff to Precipitation 75
3.3.4.2 Evaluation of Intensive Street Sweeping as a Control Measure 75
3.3.4.3 Load Reduction Analysis 77
3.4 The Modeling Effort 94
3.4.1 Receiving Water Modeling 94
3.4.2 Use of the Matrix Manipulation Model 95
3.4.3 Load Reduction Analysis 96
3.4.3.1 Stream and Overland Runoff 96

TABLE OF CONTENTS (Cont'd)

Section | Page

3.4.3.2 Equal Load Reductions ... 96
3.4.3.3 Site-Specific Controls ... 96
3.4.4 Alternative Plans ... 97
3.5 The Salmonella Study ... 97
3.5.1 Introduction ... 97
3.5.2 Findings ... 98
3.6 References Cited ... 101

4 The Surface Water Component; Remainer of the Island ... 103
4.0 Introduction ... 103
4.1 Nassau County ... 104
4.1.1 General Description ... 104
4.1.2 Stormwater Runoff Pollutant Loads ... 105
4.1.3 Current Descriptions Affecting Certification ... 106
4.1.4 Opportunities for Control Measure Application to Protect or Improve Water Quality ... 108
4.2 Suffolk County ... 109
4.2.1 General Description ... 109
4.2.2 Stormwater Runoff Pollutant Loads ... 110
4.2.3 Current Conditions Affecting Certification ... 111
4.2.4 Opportunities for Control Measure Application to Protect or Improve Water Quality ... 112
4.3 Priorities for Action or Further Investigation ... 114
4.4 References Cited ... 114

5 Findings, Conclusions, and Plan Recommendations ... 115
5.0 Introduction ... 115
5.1 Findings and Conclusions ... 115
5.1.1 Groundwater ... 115
5.1.2 Surface Water ... 117
A. General Findings and Conclusions ... 117

TABLE OF CONTENTS (Cont'd)

Section

Page

B. Site-Specific Findings and Conclusions ... 120
1. Perry Avenue, Bayville, Nassau County ... 120
2. Unqua Pond, Massapequa, Nassau County ... 121
3. Central Avenue, Deer Park, Suffolk County ... 121
5.2 Recommendations ... 122
5.2.1 Groundwater ... 122
5.2.2 Surface Water ... 122
5.3 Implementation Program ... 123
5.3.1 Determination of Priorities ... 123
5.3.2 Selection of Implementing Agencies ... 123
5.3.3 The Program ... 124
5.4 Needed Research ... 130
5.4.0 Introduction ... 130
5.4.1 Groundwater Research ... 130
5.4.2 Surface Water ... 131
5.5 References Cited ... 131
6 Annotated Bibliography ... 133

Appendix

Page

A Nationwide Urban Runoff Program Participants ... A-1
B New York State Environmental Conservation Law and Regulations Affecting the Taking of Shellfish ... B-1
C Microorganisms in Stormwater—A Summary of Recent Investigations (U.S. Geological Survey 80-1198) ... C-1
D Control Measure Evaluation (Lawler, Matusky and Skelly Engineers and Fanning and Phillips) ... D-1
E Waterfowl ... E-1
1. The Effect of Waterfowl Activities on Pond Water Quality ... E-2
2. Report on Waterfowl Count on the South Shore of Nassau and Suffolk Counties ... E-3
F Stormwater Runoff Modeling on South Shore of Long Island (Lawler, Matusky and Skelly Engineers, and Fanning and Phillips) ... F-1
G Calculation of the Value of the Standing Crop of Hard Clams Found in Uncertified Portions of Selected Nodes in Suffolk County ... G-1
H Salmonella Study—Progress Reports ... H-1

LIST OF FIGURES

2-1	Location of Recharge Basins used for Storm Runoff on Long Island in 1969. (From Seaburn and Aronson, 1973)	8
2-2	Location of Recharge Basins Studied	9
2-3.1	Topographic Map and Aerial Photograph of Drainage Area at Centereach	10
2-3.2	Topographic Map and Aerial Photograph of Drainage Area at Huntington	11
2-3.3	Topographic Map and Aerial Photograph of Drainage Area at Laurel Hollow	12
2-3.4	Topographic Map and Aerial Photograph of Drainage Area at Plainview	13
2-3.5	Topographic Map and Aerial Photograph of Drainage Area at Syosset	14
2-4	Schematic Diagram of Instrumentation at each Recharge Basin	16
2-5	Runoff/Precipitation Relationship at Centereach, Huntington, Laurel Hollow, Plainview, and Syosset	25
2-6	Hydrograph/Hyetograph, and Pollutographs for Storm of June 5, 1982, at Centereach	30
2-7	Hydrograph/Hyetograph, and Pollutographs for Storm of February 20, 1981, at Huntington	31
2-8	Hydrograph/Hyetograph, and Pollutographs for Storm of February 1, 1981, at Laurel Hollow	32
2-9	Hydrograph/Hyetograph, and Pollutographs for Storm of February 1, 1981, at Plainview	33
2-10	Hydrograph/Hyetograph, and Pollutographs for Storm of April 23, 1981, at Syosset	34
2-11	Approximate Depth to Groundwater on Long Island, in Feet	40
3-1	Map Showing Uncertified or Conditionally Certified Areas on Long Island	46
3-2	Map Showing Study Sites for Surface Water Investigations	46
3-3	Topographic Map and Aerial Photograph of Perry Avenue Site, Bayville	47
3-4	Certified Shellfish Areas of Mill Neck Creek	48
3-5	Sampling Basins–In-Line Storage System: Perry Avenue, Bayville	50
3-6	Facsimile of In-Line Storage System: Perry Avenue, Bayville	53
3-7	Topographic Map and Aerial Photograph of Unqua Pond, Massapequa	59
3-8	Unqua Pond, Massapequa: Total Coliform, Percent Reduction vs. f	71
3-9	Unqua Pond, Massapequa: Fecal Coliform, Percent Reduction vs. f	71
3-10	Unqua Pond, Massapequa: Fecal Streptococci, Percent Reduction vs. f	72
3-11	Unqua Pond, Massapequa: Non-Fecal Coliform, Percent Reduction vs. f	72
3-12	Central Avenue Site, Deer Park, Stormwater Drainage System	73
3-13	Central Avenue Site: Amounts of Runoff and Infiltration Relative to Total Rainfall for Sampled Storm Events	77

LIST OF FIGURES (Cont'd)

3-14	Central Avenue Site: Relationship of Runoff to Rainfall for Sampled Storms	78
3-15	Central Avenue Site: Rainfall Hyetograph and Runoff Hydrograph	84
3-16	Central Avenue Site: Total Coliform, Fecal Coliform, and Fecal Strep Pollutographs: Storm Event 10-23/24-82	84
4-1	Map Showing Boundaries of Contributing Drainage Areas	105
	Appendix A	
1	Study Sites for EPA's National Urban Runoff Program	A-2
	Appendix C	
1	Hydrograph and Densities of Fecal Coliform and Fecal Streptococcal Bacteria in a Small Stream near Houston, Texas, During a Storm	C-5
2	Bacterial Populations in Runoff Samples, Taken at Stormwater Outfall, Burlington, Ontario	C-5
3	Persistence of Selected Bacterial Strains in Stormwater	C-9
	Appendix D	
5.2-1	Coliform Reductions (Percent Reduction vs. Time)	D-5
5.2-2	Dye Survey at Unqua Pond (Comparison of Effluent Flow and Dye Levels)	D-6
5.2-3	Dye Survey at Unqua Pond (Corrected Dye Load and Effluent Volume)	D-6
5.2-4	Dye Survey at Unqua Pond (Coliform Data)	D-6
5.2-5	Schematic Detail of Gabion	D-10
5.2-6	Alternate Gabion Placement	D-11
5.2-7	Alternate Gabion Placement	D-13
5.3-1	Probability of Occurrence; Hourly Rainfall Intensities for Long Island	D-14
5.3-2	Average Long-Term Performance of Infiltration Sites	D-15
5.3-3	Low Level Dam for Use in Streams	D-17
	Appendix E	
1	Overall Map Showing Waterfowl Study Sites	E-3
2	Massapequa Reservoir Study Site	E-4
3	Unqua Pond Study Site	E-5
4	Tackapausha (Seaford) Pond Study Site	E-5

Appendix F

C-2.0-1 Model Segmentation and Shellfish Areas F-5
C-4.0-1 Nassau County Coliform Data F-15
C-4.0-2 Verification Run of Matrix Manipulation Model F-15
C-4.0-3 Verification Run of Matrix Manipulation Model F-16
C-5.0-1 MMM Results for Overall Load Reductions, Far-Shore Nodes 2-12 ..... F-20
C-5.0-2 MMM Results for Overall Load Reductions, Far-Shore Nodes 13-25 ..... F-20
C-5.0-3 MMM Results for Overall Load Reductions, Far-Shore Nodes 27-39 ..... F-20
C-5.0-4 MMM Results for Overall Load Reductions, Near-Shore Nodes 5-10 ..... F-21
C-5.0-5 MMM Results for Overall Load Reductions, Near-Shore Nodes 11-19 ..... F-21
C-5.0-6 MMM Results for Overall Load Reductions, Near-Shore Nodes 20-23 ..... F-21
C-5.0-7 MMM Results for Overall Load Reductions, Near-Shore Nodes 40-51 ..... F-21
C-5.0-8 MMM Results for Overall Load Reductions, Suffolk Nodes 52-55 ..... F-22
C-5.0-9 MMM Results for Overall Load Reductions, Suffolk Nodes 76-84 ..... F-22

Addendix G

G-1 (C-2.0-1) Model Segmentation and Uncertified Shellfish Areas G-5
2-3 Distribution an Abundance of Mercenaria Mercenaria G-7
2-4 Size Comparison of Hard Clam Population G-9
2-5 Distribution and Abundance of Seed Clams (Tongs) G-11

Appendix H

1 DEAE-Cellulose Column Separation of S. Typhimuriums and E. Coliform H-6
2 Effect of Temperature on S. Typhimurium in Distilled Water H-7
3 Effect of Temperature and pH on S. Typhimurium in Buffered Distilled Water H-8
4 Effect of Temperature and pH on S. Typhimurium in Buffered Distilled Water H-8
5 Effect of Temperature and pH on S. Typhimurium in Buffered Pond Water H-9
6 Effect of Temperature and pH on S. Typhimurium in Buffered Salt Water H-9

LIST OF TABLES

2-1	Physical Characteristics of Recharge Basins Studied	9
2-2	Standard Chemical Analysis	17
2-3	EPA Priority Pollutants	17, 18
2-4	Station Numbers Used	18
2-5	Number of Storm Events Sampled per Site, by Season	19
2-6	Storm Characteristics	19
2-7	Stormwater Runoff Sampling program: Source of Sample and Type of Analyses Performed	20
2-8	Priority Pollutants Sampling Program	21
2-9	Precipitation, Runoff, and Runoff Precipitation Ratio for Samples Storms	22,23
2-10	Median and Range of Runoff Precipitation Ratio in Precent	24
2-11	Median Value all Stormwater (SW), Groundwater (GW), and Precipitation (PR) Data	26-29
2-12	Priority Pollutants – Acid and Base/Neutral Compounds Reflected in µg/l	35
2-13	Priority Pollutants: Volatile Compounds, Phenols, and Cyanide Detected, in µg/l	36
2-14	Priority Pollutants Detected in Excess of New York State Guidelines	37
2-15	Minimum, Maximum, and Median Number of Bacteria (MPN) in Stormwater for all Samples, in MPN per 100 ml	37
2-16	Minimum, Maximum, and Median Number of Bacteria (MPN) per Storm for all Samples storms, per Acre per Inch of Precipitation	38
2-17	Seasonal Comparison of Minimum, Maximum, and Median Number of Bacteria (MPN) per Storm for all Sampled Storms, per Acre per Inch of Precipitation	38
2-18	Fecal Coliform to Fecal Streptococci Ratio	39
2-19	Load, in Pounds, of Selected Constituents in Stormwater and Load Reaching the Water Table at the Recharge Basins	41, 42
3-1	Perry Avenue, Bayville: Stormwater Runoff Sampling Program	51
3-2	Bayville and Massapeqia Study: Site Runoff Pollutant Constituents	51
3-3	Perry Avenue, Bayville: Storm Event Characteristics	52
3-4	Perry Avenue, Bayville: Event Mean Concentrations (EMC)	54
3-5	Perry Avenue, Bayville: Bacteriological Loads; Total Coliform, Fecal Coliform, Fecal Streptococci	54
3-6	Perry Avenue, Bayville Study Site: Fecal Coliform/Total Coliform; Fecal Coliform/Fecal Streptococci	55
3-7	Perry Avenue, Bayville: Selected Inorganic Chemical Parameters	55
3-8	Perry Avenue, Bayville: Precipitation, Runoff and Runoff Coefficient	57
3-9	Perry Avenue, Bayville: Infiltration Rate Observations	57

LIST OF TABLES (Cont'd)

3-10 Unqua Pond, Massapequa: Stormwater Runoff Sampling Program 61
3-11 Unqua Pond, Massapequa: Storm Event Characteristics 62
3-12 Unqua Pond, Massapequa: Storm Event Runoff Coefficients 62
3-13 Unqua Pond Study Site: Fecal Coliform Load/Total Coliform Load; Fecal Coliform Load/Fecal Streptococci Load 63
3-14 Unqua Pond, Massapequa: Selected Chemical Parameters 64
3-15 Unqua Pond, Massapequa: Influent and Effluent Bacteriological Loads; Percent Reduction—Total Coliform 65
3-16 Unqua Pond, Massapequa: Influent and Effluent Loads; Percent Reduction, Fecal Coliform 66
3-17 Unqua Pond, Massapequa: Influent and Effluent Bacteriological Loads; Percent Reduction—Fecal Streptococci 66
3-18 Unqua Pond, Massapequa: f-Factor Versus Bacterial Indicator Reduction 71
3-19 Suffolk County Dept. of Health Services: Sampling Parameters and Color Coding for Sample Bottles 74
3-20 Central Avenue Site: Amount and Type of Analyses Performed 76
3-21 Central Avenue Site: Storm Characteristics 76
3-22 Central Avenue Site: Precipitation, Runoff, Infiltration, Runoff Coefficient 77
3-23 Central Avenue Site: Cubic Yards of Road Debris Removed by Street Sweeping 78
3-24 Central Avenue Site: Total Coliform: EMC, Load and Load Factor 79
3-25 Central Avenue Site: Fecal Coliform: EMC, Load and Load Factor 80
3-26 Central Avenue Site: Fecal Streptococci: EMC, Load and Load Factor 81
3-27 Central Avenue Site: Ratios of Fecal Coliform/Fecal Strep and Fecal Coliform/Total Coliform 82
3-28 Central Avenue Site: Warm Weather, Cold Weather and L.I. 208 Study Bacterial Load Factors 83
3-29 Central Avenue Site: Total Coliform, Fecal Coliform, Fecal Strep Load Factors; Storm Event of 10-23-81 thru 10-24-81 83
3-30 Central Avenue Site: Statistical Evaluation of Bacterial EMCs and Loads (All Data) 85
3-31 Central Avenue Site: Statistical Evaluation of Bacterial EMC Reduction Due to Street Sweeping—Summer Data 86
3-32 Central Avenue Site: Total Kjeldahl Nitrogen: EMC, Load and Load Factors 87
3-33 Central Avenue Site: NH_3-Nitrogen: EMC, Load and Load Factors 88
3-34 Central Avenue Site: NO_3-Nitrogen: EMC, Load and Load Factors 89
3-35 Central Avenue Site: NO_2-Nitrogen: EMC, Load and Load Factors 90
3-36 Central Avenue Site: Total Phosphorus: EMC, Load and Load Factors 91
3-37 Central Avenue Site: Chloride: EMC, Load and Load Factors 92
3-38 Central Avenue Site: Total Suspended Solids: EMC, Load and Load Factors 93
3-39 Central Avenue Site: Statistical Evaluation of TSS, TKN, TP-EMC's and Loads 94

LIST OF TABLES (Cont'd)

3-40	Central Avenue Site: Street Cleaning Comparison (All Data)	94
3-41	Shellfish Openings for Combinations of Load-Reductions	97
3-42	Summary of Major Components of Plan Alternatives	98
3-43	Salmonella Study—Summary of Positive Isolation, March-December 1982	98
3-44	Comparison of the Levels of Salmonella Found in Surface Water and Sewage	99
3-45	Comparison of the Frequency of Detection of Salmonella with Levels of Fecal Coliform	100
3-46	Comparison of the Frequency of Detection of Salmonella with Levels of Total Coliform	100
3-47	Comparison of the Frequency of Detection of Salmonella with Levels of Fecal Streptococci	101
4-1	Nassau County Surface Water Acreage	104
4-2	Nassau County Relative Contribution of Total and Fecal Coliform from Runoff, Stream Base Flow, and Point Source to Surface Waters	106
4-3	Suffolk County—Total Area of Shellfishing Waters and Area Open to Shellfishing	110
4-4	Comparison Between NURP and L.I. 208 Study Estimates of Annual Runoff Bactrial Loads to Surface Water	111
4-5	Suffolk County Relative Contribution of Total Fecal Coliform from Runoff, Stream Base Flow, and Point Sources to Surface Waters	112
4-6	Selected Areas Uncertified for Shellfishing and Contributing Drainage Area	113
5-1	Percent of Runoff Expected to Infiltrate in Streams Reaches Dried because of Groundwater Lowering Caused by Sewering	118
5-2	Summary of Costs and Degrees of Control of Plan Alternatives	119
5-3	Summary of Proposed Implementation Program and Schedule	126-130

Appendix A

A-1	Prototype Projects in the Nationwide Urban Runoff Program	A-3,4

Appendix C

C-1	Densities of Indicator Bacteria in Stormwater	C-6
C-2	Densities of Pathogens in Stormwater from Baltimore, Maryland	C-7

Appendix D

5.2-1	Bacterial Die-Off Analysis	D-8
5.4-1	Coliform Water Characteristics of Dogs, Ducks and Geese as Compared to Residential Land	D-18
5.4-2	In Situ Control Sites: Fecal Coliform/Fecal Streptococcus Ratios	D-19

LIST OF TABLES Cont'd

Appendix E

1	Massapequa Reservoir: Log Average Coliform Counts (MPN/100 ml) 11/79 to 5/80	E-6
2	Massapequa Reservoir: Chemical Anaylsis Results (mg/l)	E-6
3	Unqua Pond: Log Average Coliform Counts (MPN/100 ml) 11/79 to 5/80	E-7
4	Unqua Pond: Chemical Analysis Results (mg/l)	E-7
5	Tackapausha Pond: Log Average Coliform Counts (MPN/100 ml) 11/79 to 5/80	E-7
6	Tackapausha Pond: Chemical Analysis Results (mg/l)	E-7
IX	List of Ponds Surveyed–Waterfowl Count	E-9
X	Description of Species	E-10
XI	Waterfowl Count: Carmens River Bird Count	E-10—E-16

Appendix F

C-2.0-1	Stream Characteristics Used in the Hydrodynamic and Water Quality Models	F-3
C-2.0-2	Point Sources	F-3
C-2.0-3	Storm Event Characteristics	F-6
C-3.0-1	Steady-State Matrix of MMM	F-8
C-3.0-2	MMM Transient Matrix, Discharge to Node 11	F-9
C-3.0-3	MMM Transient Matrix, Discharge to Node 87	F-10
C-3.0-4	Long Island Rain Gauge Statistics	F-11
C-3.0-5	Nodes that Contain Certified and Uncertified Shellfish Beds	F-12
C-3.0-6	MMM Sample Model Output	F-12, F-13
C-4.0-1	Statistical Reliability of MMM	F-16
C-4.0-2	Effect of Total Rainfall of MMM Results	F-16
C-5.0-1	Runoff Distribution by Model Mode	F-18
C-5.0-2	Coliform Load Reductions and Shellfish Bed Openings as Predicted by MMM	F-18

Appendix G

G-1	Values of Shellfish in Uncertified Areas of Selected Nodes in Suffolk County	G-3

Appendix H

1	Environmental Samples for Salmonella and Indicator Bacteria Analysis March-October 1982	H-9—H-12
2	Positive Salmonella Samples	H-13, H-14

Prefatory Comments

The Development of the Long Island Comprehensive Waste Treatment Management Plan, completed in 1978, not only produced some important conclusions but also raised a number of questions that could not be totally resolved during the course of that federally supported undertaking.

A major conclusion and an unanswered question related to urban stormwater runoff. The conclusion—that stormwater runoff is generally the single most significant source of pollution, especially bacterial pollution, affecting the fresh surface waters and the nearshore marine environment—has been further reinforced by the findings of other 208 studies elsewhere in the nation. The unanswered question—does the continued use of the recharge basin, a device for the disposal of runoff and its recharge to groundwater, pose a threat to the quality of the bi-county water supply—has caused increasing concern as Long Islanders have become aware of the presence of organic chemicals in some private and public wells.

In 1977, the Congress responded to the growing recognition that without a successful attack on nonpoint as well as point source pollution problems it was unlikely that the water quality goals of P.L. 92-500 could be met. The Nationwide Urban Runoff Program (NURP) in which Long Island has been fortunate to participate, is an attempt to understand and deal with the most important of the nonpoint sources of pollution.

One part of the Long Island NURP investigations focused on the role of the recharge basins or sumps. Although it was known that the basins were effective in detaining and recharging runoff, little was known of the potential for contamination, if any, associated with their use. Were the basins only devices for getting rid of unwanted runoff and returning much needed water to the aquifer or were they also devices for the concentration of pollutants in runoff and their swift transmission to Long Island's only source of water supply? For the most part, the results of the investigations have proved to be positive. In sum, the basins appear to work in a generally satisfactory fashion. The limited results of this study indicate that the continued use of recharge basins is justified and warranted. Coliform and fecal streptococcal bacteria were found in runoff but not in the groundwater beneath the recharge basins. The concentrations of other pollutants, which were generally relatively low in runoff, were even lower in the groundwater beneath the basins. It appears that infiltration through the soil is an effective mechanism for the attenuation of some of the heavy metals and organic compounds. These findings were as true for the unlined basins as for the recharge basin at Centereach, which was built with a plastic lining. It also appears that, contrary to the widely held view, the removal of vegetation from the basin floor is not necessary, and that the vegetation may actually facilitate the infiltration of storm waters.

The Long Island 208 report accorded a high priority to further research dealing with stormwater runoff. A second part of the Long Island NURP investigations focused on the feasibility of and various techniques for achieving improvements in water quality that would allow New York State to reopen areas that are currently legally closed or uncertified for the taking of shellfish. The findings clearly indicate the complexity, costs, and often questionable feasibility of significant remediation through the application of some of the control measures studied; and the importance of preventative action to preclude the degradation of the satisfactory water quality that exists in many areas.

Although this study offers no simple cures for urban runoff problems, it does present recommendations for actions that can be taken by all levels of government to mitigate the impacts of stormwater runoff pollutant loads.

This report is the product of a United States Environmental Protection Agency (E.P.A.) supported, three year, $2.5 million study conducted by the same Technical Advisory team that worked on the initial Waste Treatment Management Plan. The two County Health Departments, the Nassau County Department of Public Works, the Suffolk County Water Authority, the Nassau County Planning Commission, and the Long Island Regional Planning Board, together with the United States Geological Survey provided guidance and personnel for the study. In contrast with the Comprehensive Waste Treatment Management Plan, during which the Regional Planning Board utilized the services of a variety of nationally known consultants, the greater portion of this work was accomplished by the governmental agencies, with support from one consultant, Lawler, Matusky and Skelly, Engineers.

We believe this study faithfully meets the charge of E.P.A. in its required response to the Congress of the United States, which hopefully will lead to continued Federal support to achieve the national policy objectives of the Federal Water Pollution Control Act of 1972 to achieve fishable and swimmable standards for all of the waters of the country.

Lee E. Koppelman

Section 1 - Introduction

1.0 THE NATIONWIDE URBAN RUNOFF PROGRAM

Years of massive federal, state and private investments for the construction of municipal and industrial sewage treatment facilities have failed to achieve anticipated improvements in water quality. The findings of various 208 studies provided conclusive evidence that in many areas pollutant loadings contributed by non-point sources exceed those contributed by point sources; and that urban runoff is the single most important non-point source. By 1977 various investigations by the United States Environmental Protection Agency (E.P.A.) and other investigations had begun to document the role of urban runoff in contaminant transport. Yet numerous areas of uncertainty still remained. In response to this and related matters the Congress enacted *P.L. 95-217*, which amended the *Clean Water Act* by providing funds for problem assessment and planning. The Act also calls for E.P.A. preparation of a report of the findings to be delivered to the Congress in 1983. This authorization highlights the significance of stormwater runoff as a determinant of water quality. It is an attempt to improve the adequacy of information concerning, *pollutant sources, areal accumulation patterns, washoff and transport mechanisms, instream behavior of pollutants, and control effectiveness.* (Water Planning Division, E.P.A. 1978).

The Nationwide Urban Runoff Program has attempted to address some of the more critical areas of uncertainty, among them:

- the actual proportion of the total pollutant loading that can be attributed to stormwater runoff, given the presence of other point and non-point sources and conditions within the receiving waters;
- sources, washoff/transport mechanisms and receiving water impacts;
- the appropriate criteria to be used in determining the existence of a runoff problem; and
- the effectiveness and cost of proposed but relatively untried non-structural control measures.

Preceding page blank

The program is meant to obtain answers to the following questions:

- Where and under what conditions is urban runoff likely to cause water quality problems?
- What types of problems can be anticipated?
- What solutions are available, and at what cost?

Another aim was to facilitate the rapid development of the data base needed for the production of a nationwide assessment of urban runoff.

The Water Planning Division of E.P.A. devised a ten task work plan, which included a combination of E.P.A. Headquarters and Regional-local components. The latter, of which the Long Island Program is a part, comprised a series of selected demonstration projects designed to meet local as well as national needs. It was expected that the local projects or program components would produce water quality management plans that were not only appropriate but acceptable and affordable; that focused on local needs, recommended realistic control options, and proposed implementable, least cost solutions.

1.1 RELATION OF THE NATIONWIDE URBAN RUNOFF PROGRAM TO LONG ISLAND

The Nassau-Suffolk region was among the first nineteen areas chosen as potential project sites. E.P.A. selected candidate areas on the basis of geographic and climatic diversity, type of receiving water, evidence of a serious existing or suspected runoff problem, and the area wide or state agency's achievements in 208 planning.

In the fall of 1978, the Regional Office of the United States Geological Survey approached the Long Island Regional Planning 208 Technical Advisory Committee, which had continued to meet informally to discuss water quality matters, to apprise it of the opportunity to participate in the Nationwide Urban Runoff Program and to propose a cooperative undertaking to do so. Eventually 28 state or areawide agencies agreed to participate in the NURP planning effort. Six non-NURP projects furnished supplementary data. (See Appendix A for a listing of NURP participants and project locations).

Each project constituted a separate entity, often with multiple parts; each study design reflected the distinctive problems and conditions of a specific area. All, however, comprised one or more of the following tasks: characterization of pollutant types, loads and effects on receiving waters; determination of the need for control; and evaluation of various alternatives for stormwater pollution control (E.P.A., March 1982).

The E.P.A.'s decision to seek broad participation in the $30 million Nationwide Urban Runoff Program and to host several national meetings has already fostered the inter-agency exchange of information. It appears likely that the completion of the Program and its component projects will generate further interest in *transferable solutions* to runoff problems and new requests for information. For this reason, a brief description of the two county Long Island region and of the resource is in order.

1.2 DESCRIPTION OF THE AREA

Nassau and Suffolk comprise a 1200 square mile area of glacial moraine and outwash plains located directly east of New York City. Long Island Sound lies to the north; the Atlantic Ocean to the south and east. Although the region is only a little more than 100 miles long and 20 miles wide at its widest point, bi-county stream, lake, river, bay, ocean and Sound water-frontage exceeds 1,000 linear miles. The climate is temperate, with a mean daily maximum temperature of 81.9°F during the warmest month, July; mean daily minimum temperature of 19.0°F during the coldest month, January (Nagle, 1975 and 1978). The Island-wide average rainfall is 44 inches, and is fairly well distributed throughout the year.

Approximately 2.6 million people reside in the Nassau-Suffolk area; two-thirds of them in the western third of the region. The development in the western and central portions is primarily residential, with moderate to higher suburban densities—generally no more than five to ten dwelling units per acre—gradually giving way to lower densities as one proceeds toward the north shore in Nassau and western Suffolk and toward the more recently subdivided areas in western and central Suffolk. The eastern portion of Suffolk remains semi-rural, with a mix of agricultural, resort, and residential land uses; open fields; and woodlands.

1.3 WATER QUALITY PLANNING ON LONG ISLAND

The quantity and quality of Long Island's groundwater and the quality of its surface water have long been concerns of officials and residents who recognized their dependence on groundwater for potable supplies and on the surface waters for recreation and for the economically important tourism and fisheries industries.

During the past three decades an increasing number of federal, state, local, and even privately funded studies have focused on one or another aspect of Nassau and Suffolk's water resources. However, it was not until 1975, well after the Congressional enactment of *Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500),* that coordinated comprehensive water quality management planning became a reality on Long Island. The Governor's December 1974 designation of the Nassau-Suffolk Regional Planning Board—now known as the Long Island Regional Planning Board—as the areawide planning agency, was followed by a E.P.A.'s award of a $5.2 million grant for a three year study of both surface water and groundwater quality problems in the bi-county area.

Findings of the 208 Study suggested that urban stormwater runoff might be a significant source of groundwater contamination. A major concern was that the more than 3000 recharge basins or sumps* that dot the Long Island land-

* Recharge basins or sumps are excavated areas, averaging about an acre in size, that receive the collected runoff from residential, commercial, and industrial areas and from highways, and permit it to percolate through moderate to highly permeable sand and gravel deposits to the water table.

scape might be functioning as conduits facilitating the passage of pollutants from the surface of the land to the water table aquifer and in some instances, to the deeper aquifers. The question of the role of the recharge basins in contaminant transport and their impact on groundwater quality attracted little or no attention from the time of the introduction of basins on Long Island in the 1930's until suspected organic contamination of drinking water emerged as a major concern in the mid-1970's.

The recharge basin has long been regarded as an extremely useful device serving a dual function: the provision of effective surface drainage at moderate cost in inland areas, especially those where ponding of runoff might otherwise occur; and the partial replenishment of the Upper Glacial or water table aquifer through recharge of fresh water that might otherwise be lost as a result of evaporation from impervious surfaces or diversion to coastal waters.

The 208 Study definitively implicated stormwater runoff as the major source of bacterial loading to coastal waters. It thus established a clear causal relationship between urban runoff and the closure of considerable portions of the shellfish areas, especially those along the south shore; and the occasional closure of public beaches. Modeling studies of eight bays, including extensive pre-storm and post-storm sample collection and analysis, indicated that in most parts of the region, runoff contributes more than 95% of the annual bacterial loading to the bays. This bacterial loading is apparently of nonhuman origin. The studies also implicated runoff as a contributor of inorganic chemicals, organic matter and sediment, and, possibly organic chemicals.

There is no doubt that past and present stormwater management practices have adversely affected surface water quality, and that poor water quality has, in turn, resulted in the denial of a beneficial use. The elevated coliform counts associated with urban runoff have been responsible for repeated or continuing contravention of the public health standards for the certification of shellfish waters (Appendix B) and the relatively infrequent contravention of the less restrictive standard for the operation of public beaches. The current ban on the harvesting of shellfish in approximately one-fourth of the most productive portions of the bays, containing an estimated one-third of the clams, seriously affects the hard clam industry, which reported a catch worth $17.4 million dockside value in 1981. It also affects commercial shellfishermen who specialize in other species, and a host of recreational clam diggers.

Given the economic and social impacts of the shellfish area closures, on the livelihood and recreation of Long Islanders, it is hardly surprising that questions have been raised concerning the reliability of the total and fecal coliform standard as a public health yardstick for the measurement of potential risk from the ingestion of shellfish. The continuing illegal harvesting of shellfish from uncertified waters, whether for personal consumption or sale, combined with the apparent low incidence of shellfish-transmitted disease, seems to suggest that administrative convenience, rather than a well documented causal relationship and predictive capability, may be the strongest argument in favor of retention of the existing standards.

1.4 PROBLEMS SELECTED FOR STUDY: THE LONG ISLAND CONTRIBUTION TO THE NATIONAL EFFORT

The decision to participate in the Nationwide Urban Runoff Program presented the Long Island Regional Planning Board with an opportunity and a responsibility.

It afforded an opportunity to expand the continuing planning activities initiated shortly after the completion of the *208 Areawide Waste Treatment Management Plan,* by providing sufficient funding to allow the Board and the cooperating agencies to address several high priority runoff-related concerns; namely, to verify or refute a critical assumption concerning the groundwater quality impacts of the use of recharge basins; to confirm or modify 208 findings regarding pollutant loadings by land use category; to determine the relative importance of animal as opposed to human sources of coliform bacteria; and to investigate the frequency and extent of the occurrence of a human pathogen, salmonella, in stormwater runoff. It imposed a responsibility to contribute specified precipitation, runoff and receiving water data to E.P.A.'s rapidly expanding national data base as part of that agency's Congressionally mandated effort to gain a better understanding of the importance of runoff-related pollution and of the most appropriate, least-cost strategies for mitigating unacceptable water quality impacts.

The bi-county component of the Nationwide Urban Runoff Program was designed to meet local and national needs. The Water Division of E.P.A. suggested that the prime focus should be the investigation of the effects of urban runoff-borne contaminants, especially toxics, on the water supply. However, considerable discussion among the proposed participants with E.P.A. Headquarters staff and its NURP consultants resulted in an expansion of the project scope to include stormwater runoff impacts on marine waters. In its final form, the Long Island program provided for the further investigation of the source, type, and fate of pollutants in runoff on Long Island, and an evaluation of the changes in runoff quality; that is, the reduction in pollutant loading that could be achieved through the adoption of selected best management practices. It attempted to respond not only to relevant 208 questions and findings, but also to the doubts as to the scientific validity of the coliform standards as a measure of potential pathogenic effects in humans attributable to shellfish consumption.

1.5 THE WORK PLAN

Following the normal delay in start-up time attributable to the need to prepare a detailed work plan and unanticipated delays attributable to the necessity for budgetary revisions to resolve a last minute funding problem and to unfavorable weather conditions, the United States Geological Survey and the county agencies commenced study site instrumentation and initial sampling in the latter part of 1980.

The work plan originally identified twelve separate tasks, nine of a technical nature. The tasks involved:

- study site and monitoring station selection
- baseline data collection, analysis, and evaluation
- control measure application or modification
- post-control measure data collection, analysis, and effectiveness evaluation
- relative cost, cost-effectiveness, and control measure applicability assessment
- management program development

A long dry spell coupled with delays in the procurement of monitoring equipment necessitated some changes in program scope and scheduling. The excessive cost of constructing one of the proposed control measures, the energy dissipator, in accordance with the engineering consultant's plans and specifications resulted in a decision to drop the proposed control measure evaluation at the Carlls River site.

1.6 REPORT DESCRIPTION

This volume is divided into two parts. Part I contains the *Long Island Segment of the Nationwide Urban Runoff Program Project Report*—esentially an expansion, modification and detailing of the findings and plan recommendations relating to runoff presented in Volume I of the Long Island Waste Treatment Management Plan, published in 1978. Part II contains a series of *Appendices*, consisting of selected technical materials generated as part of the Long Island Project. Part II is an extension of Volume II of the 1978 publication.

Additional Nationwide Urban Runoff Program materials, including raw data for individual storm events, consultant memoranda and reports, and instructions and preliminary National Program reports from E.P.A. Headquarters, are available for review at the Long Island Regional Planing Board or may be accessed through the participating agencies.

The Project Report (Part I) consists of six sections.

Section One — Introduction — covers the general background, including a description of the Nationwide Urban Runoff Program, its relation to Long Island, the local role, the problems addressed and the work plan.

Section Two — The Groundwater Component — discusses the U.S. Geological Survey's investigation of the extent to which recharge basins facilitate or impede the movement of runoff-borne contaminants from the land surface to the water table, and the extent to which pollutant loadings and contaminant transfer is affected by drainage area land uses or basin characteristics. This section includes a description of the study sites and control measure effectiveness.

Section Three—The Surface Water Component: Detailed Study Areas in Nassau and Western Suffolk—discusses the Nassau County Department of Health and Suffolk County Department of Health Services investigations of contamination of surface waters, with emphasis on bacterial indicators, including a description of the study sites and control measures; the sampling program, analytical procedures, results; and an evaluation of control measures. This section also incorporates portions of the work of the engineering consultant, particularly those relating to load reduction analysis.

Section Four — The Surface Water Component: Remainder of the Island presents a general discussion of the location and extent of coliform contamination of near shore marine surface waters outside the detailed study area. It includes a revised map and description of the areas contributing surface runoff directly to streams and saltwater bodies, a recalculation of the runoff-related pollutant contribution to several bays for which the presumed drainage area boundaries were changed, and additional calculations of runoff-related pollutant loadings to a number of streams and bays that were not modeled during the initial 208 study. It deals with areas currently closed to shellfishing and assesses the likelihood of certification even with the achievement of significant reductions in runoff-related pollutant loads; and with areas now open, but subject to severe degradation and possible closure unless measures to protect water quality accompany future residential or other development.

Section Five — Findings, Conclusions and Plan Recommendations — summarizes the more important findings and conclusions, poses a series of stormwater management alternatives for surface water coliform load reduction and recommends a course of action.

Section Six — Annotated Bibliography — presents a brief description of various documents produced during the course of the Nationwide Urban Runoff Program.

Part II comprises eight appendices.

Appendix A contains a listing of the twenty-eight state or areawide agencies participating in the Nationwide Urban Runoff Program and a map indicating the location of prototype projects.

Appendix B a copy of the New York State laws and regulations relating to shellfishing.

Appendix C a report of a U.S. Geological Survey literature search dealing with microorganisms in stormwater.

Appendix D which has been excerpted from the report prepared by the Planning Board's engineering consultant, presents an evaluation of the various control measures that were considered.

Appendix E focuses on waterfowl and includes a Nassau County Department of Health report dealing with the relation of waterfowl activities on water quality in three south shore ponds and waterfowl counts for numerous south shore areas.

Appendix F presents additional material provided by the engineering consultant; in this instance, a description of the modeling effort that constituted a key element of the study.

Appendix G contains a memorandum describing a methodology for, and the results of calculations of, the value of the standing crop of hard clams in selected areas.

Appendix H presents two memoranda describing the initial investigations undertaken as part of the study of occurence of Salmonella organisms in surface waters.

1.7 REFERENCES CITED

Nagle, C.M., 1975, *Climatology of Brookhaven National Laboratory 1949 through 1973*, BNL50466, Brookhaven National Laboratory, Upton, N.Y.

Nagle, C.M., 1978, *Climatology of Brookhaven National Laboratory 1974 through 1977*, BNL40857, UC-11, Brookhaven National Laboratory, Upton, N.Y.

Water Planning Division, U.S. Environmental Protection Agency, 1978, *1978-1983 Work Plan for the Nationwide Urban Runoff Program*, Water Planning Division, U.S. Environmental Protection Agency, Washington, D.C.

Section 2 - The Groundwater Component

2.0 INTRODUCTION

Groundwater is the sole source of fresh water for the more than 2.6 million residents of Nassau and Suffolk Counties on Long Island, New York (Figure 2-1). Under natural conditions, the groundwater reservoir is recharged only by local precipitation seeping from the land surface to the water table. Since the 1920's, when Nassau County began to experience urbanization, the construction of highways and parkways, houses, shopping centers, industrial parks, and streets and sidewalks in areas that had been farmland has continuously reduced the amount of land surface through which precipitation can infiltrate to the water table. After urbanization, storm runoff from the paved surfaces was carried to streams or coastal waters through storm sewers, which resulted in a substantial loss of recharge to the groundwater reservoir.

When Nassau County recognized that natural recharge was being lost, it began, in 1935, to excavate large basins to impound stormwater so that the water could infiltrate to the groundwater reservoir through the pervious sand and gravel beds that underlie Long Island. The use of stormwater basins not only helped to conserve storm runoff and to augment the groundwater supply, but also eliminated the need for long, costly trunk storm sewers to carry runoff to coastal waters. The concept was adopted throughout Suffolk County some years later. In spite of these efforts, there remain significant areas that are not served by recharge basins because the depth to groundwater is insufficient. Therefore, large quantities of runoff are still discharged to bays.

The findings of the *Long Island Comprehensive Waste Treatment Management Plan (Koppelman, 1978)* suggested that urban stormwater runoff, routed through storm sewers to the more than 3,000 recharge basins or sumps in Nassau and Suffolk Counties (Figure 2-1), might be a significant source of pollution to the groundwater reservoir and ultimately, through subsurface outflow, to the surrounding marine waters.

The purpose of the groundwater component of the Long Island Nationwide Urban Runoff Program, carried out by the U.S. Geological Survey, New York District, Syosset Subdistrict, was to determine:

- the source, type, quantity, and fate of pollutants in stormwater runoff routed to recharge basins, and
- the extent to which these pollutants are, or are not, attenuated as they percolate through the unsaturated zone.

In order to accomplish this objective, five recharge basins, located in areas with distinct land use types, were selected for intensive monitoring during and immediately following storm events.

Preceding page blank

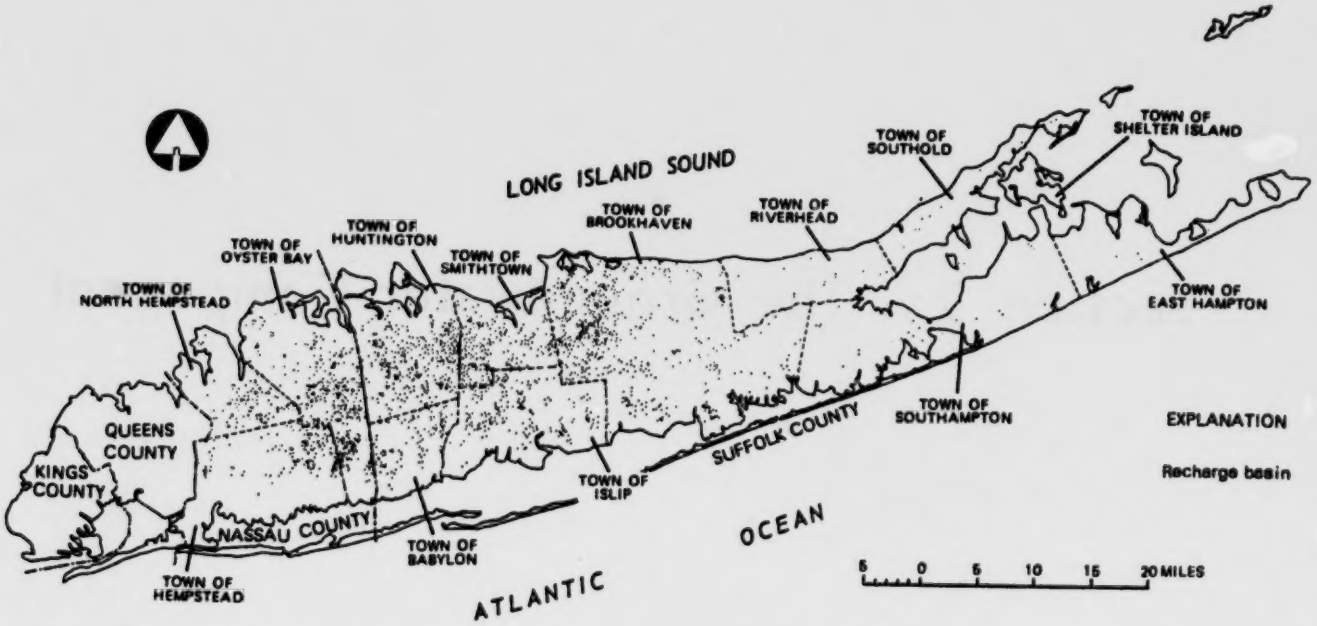


FIGURE 2-1 *Location of recharge basins used for storm runoff on Long Island in 1969 (from Seaburn and Aronson, 1973)*

2.1 DESCRIPTION OF MONITORING SITES

Five recharge basins, three in Nassau County and two in Suffolk County, were chosen for study (Figure 2-2) on the basis of the type of land use from which they receive stormwater runoff. A variety of land use types is represented. The physical characteristics of these recharge basins and their drainage areas are summarized in Table 2-1. A topographic map and an aerial photograph of each of the five drainage areas are shown in Figures 2-3.1 to 2-3.5.

2.1.1 Centereach. The recharge basin at Centereach (Figure 2-3.1) drains storm runoff from a four-lane asphalt State highway that is bordered on both sides by small commercial establishments. Although the topographic drainage area is 553 acres, the effective drainage area as determined by the New York State Department of Transportation (DOT), which owns and maintains the basin, is only 69 acres. Of this, 4.9 acres is impervious area, consisting of the state highway, driveways, and side road intersections.

The basin floor occupies about 0.5 acres and is underlain by sand and gravel. Topographic relief in the drainage area is about 10 feet.

This recharge basin was constructed in 1977 and was designated *Ecological Recharge Basin #2* by the New York State Department of Transportation. The basin bottom was lined with 30-mil polyvinylchloride sheets so that it retains water and has formed an artificial pond. The pond is stocked with aquatic animals and vegetation by the DOT. Beneath the impermeable liner there is an exfiltration system consisting of perforated pipes. When the pond level rises, the excess water flows through a filter box into the exfiltration system and ultimately recharges the groundwater.

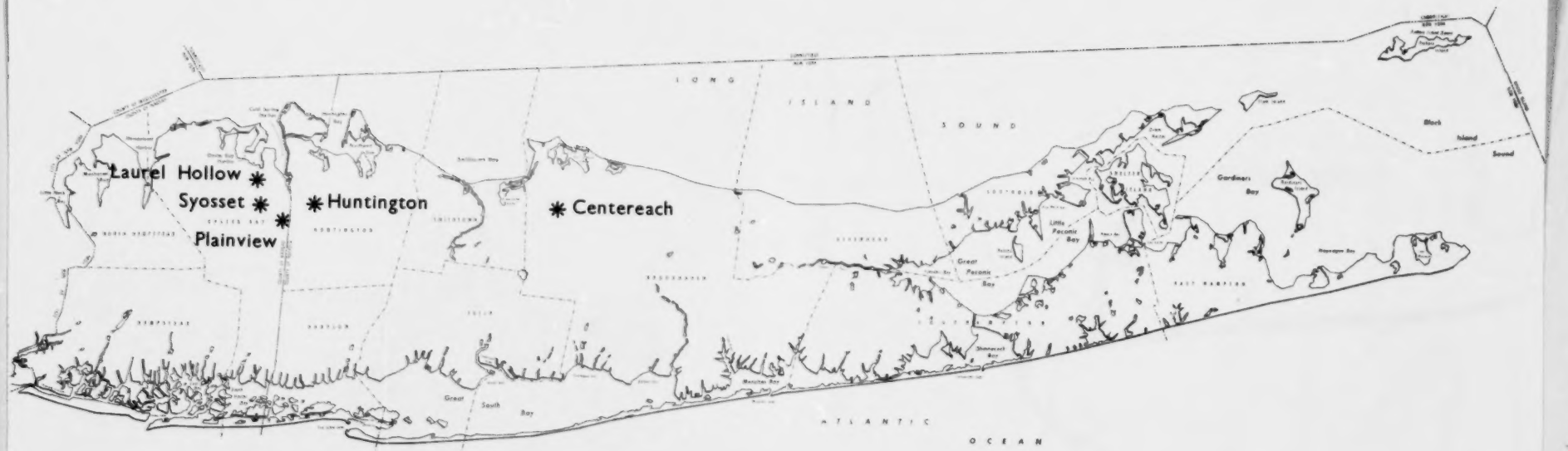


FIGURE 2-2 *Location of recharge basins studied*

Table 2-1
PHYSICAL CHARACTERISTICS OF RECHARGE BASINS STUDIED

Site Location	Land Use	Drainage Area (Acres) Total	Drainage Area (Acres) Impervious	Percent Impervious	Soil Type[a]	Depth To Ground-Water (ft)	Remarks
Centereach	strip commercial	69	4.9	7.1	Dukes sand	39	constructed with impervious liner to hold water at all times
Huntington	shopping mall, parking lot	39	39.0	100.0	Sassafrass loam	66	always contains water
Laurel Hollow	low density residential[b]	100	4.7	4.7	Haven loam	22	basin is newly constructed
Plainview	major highway	190	12.0	6.3	Haven loam	58	heavy vegetation in basin
Syosset	medium density residential[c]	28	6.3	23.0	Hempstead loam	78	

[a] Classification from Lounsbury and others (1928).
[b] 1-acre zoning
[c] 1/4-acre zoning

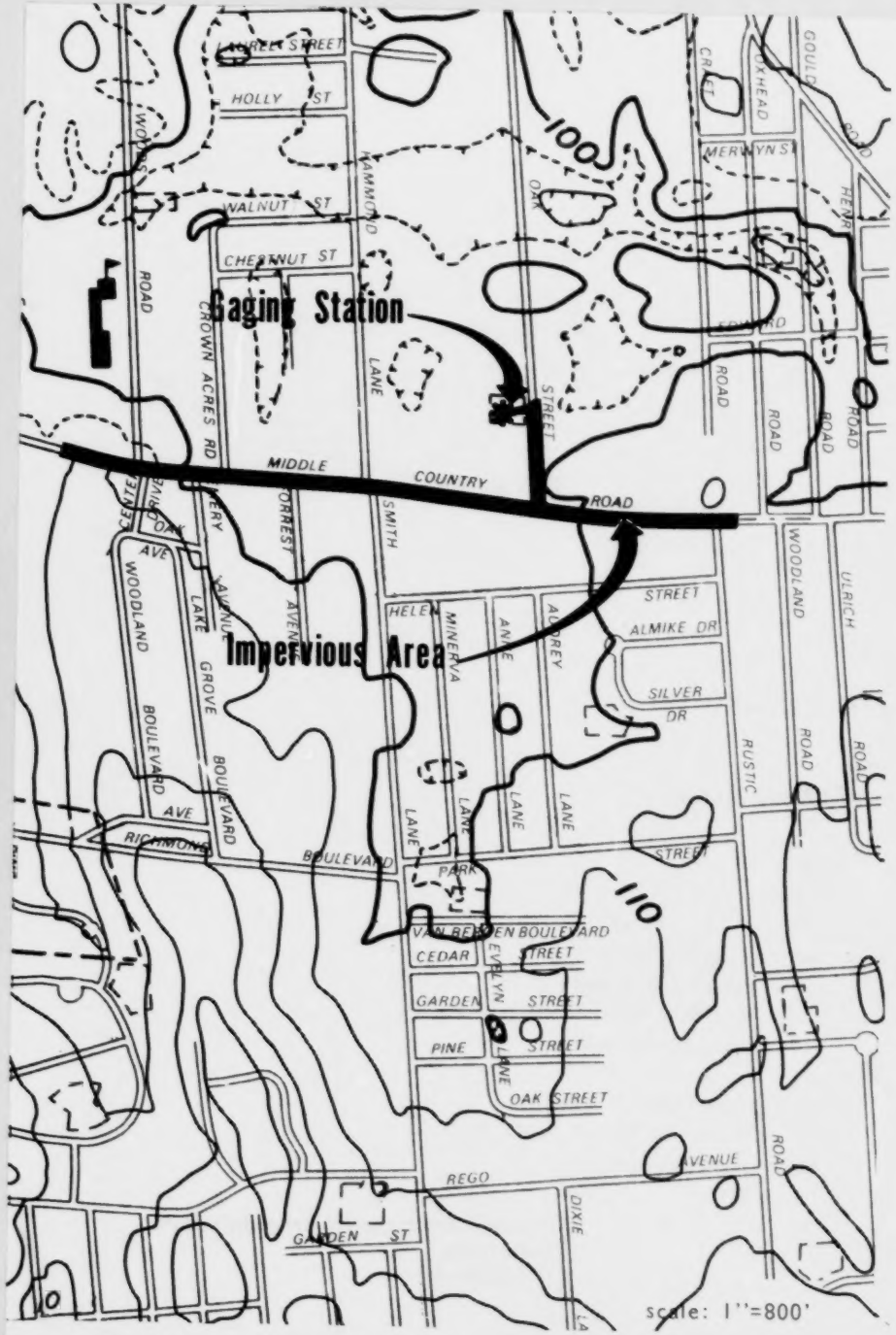
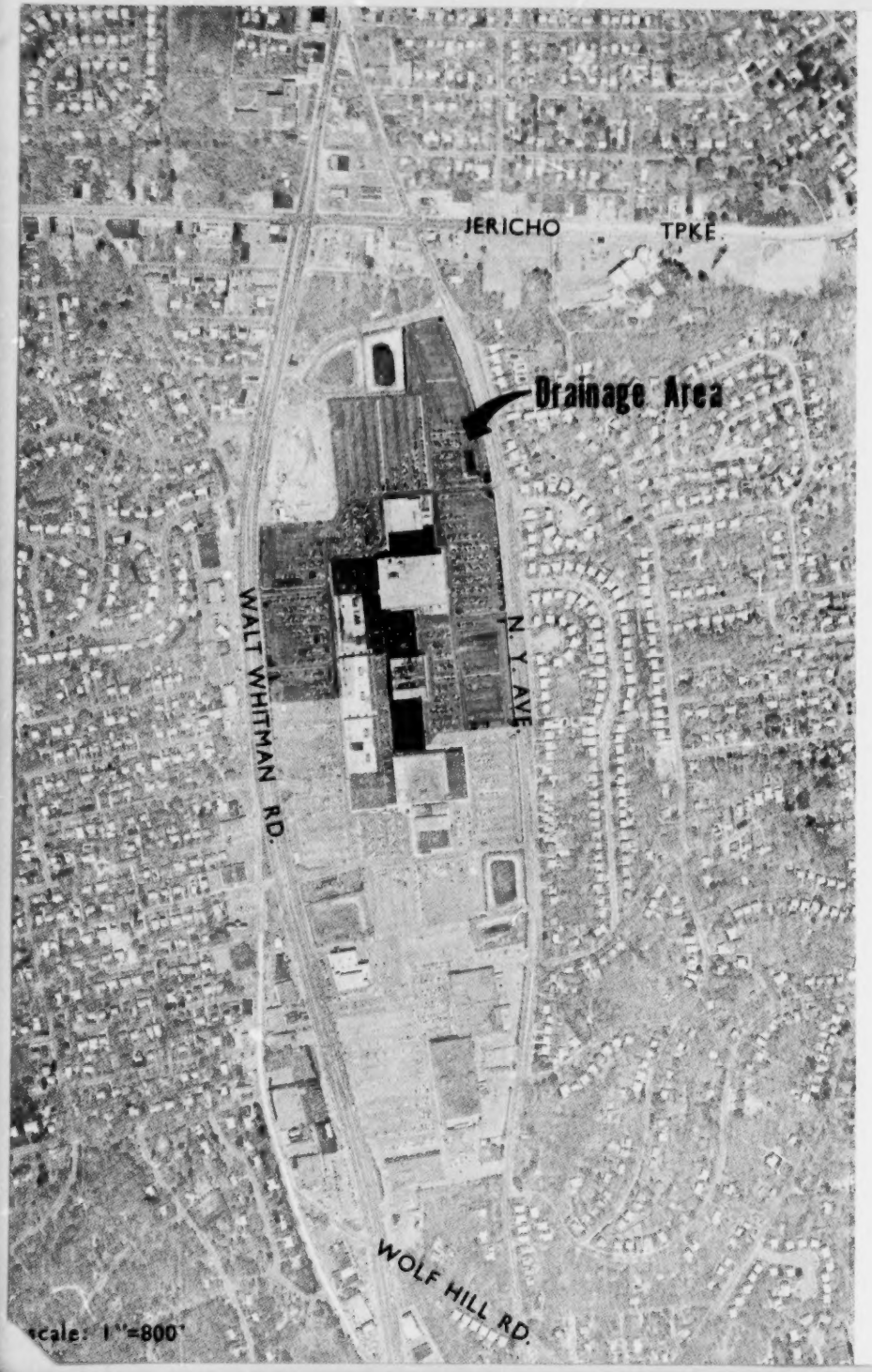


FIGURE 2-3.1 *Topographic map and aerial photograph of drainage area at Centereach*



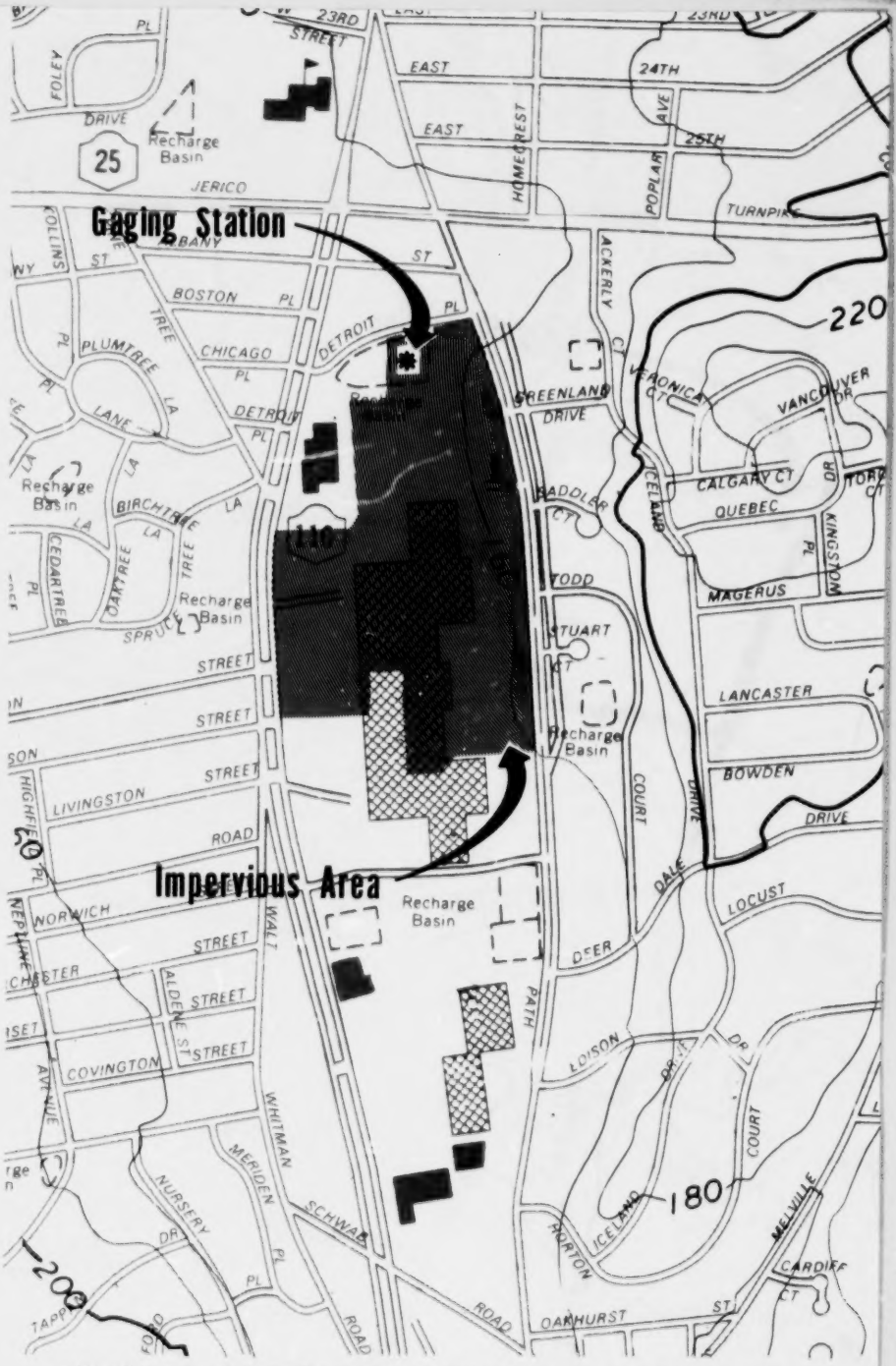
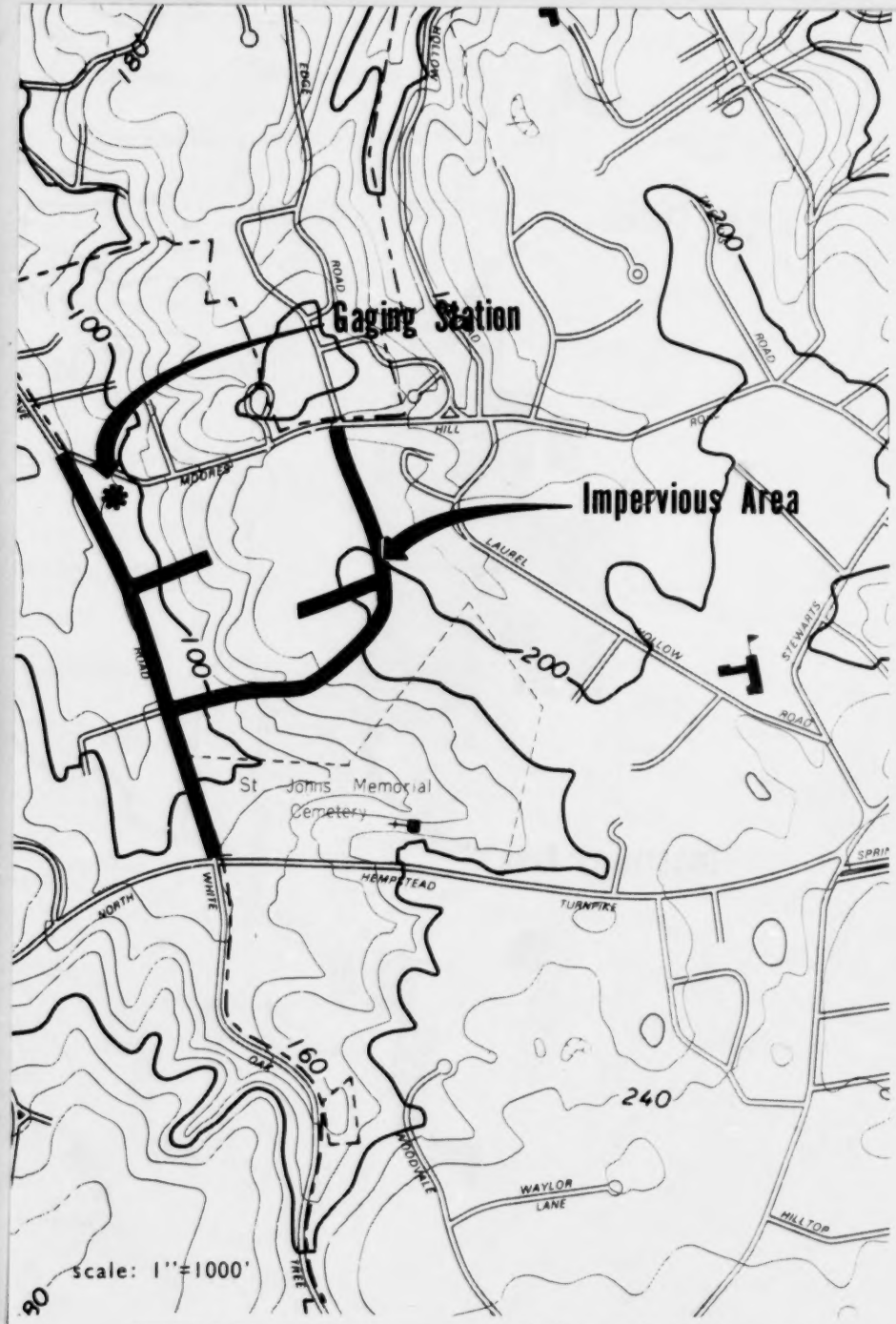


FIGURE 2-3.2 *Topographic map and aerial photograph of drainage area at Huntington*



Reproduced from best available copy.

FIGURE 2-3.3 *Topographic map and aerial photograph of drainage area at Laurel Hollow*

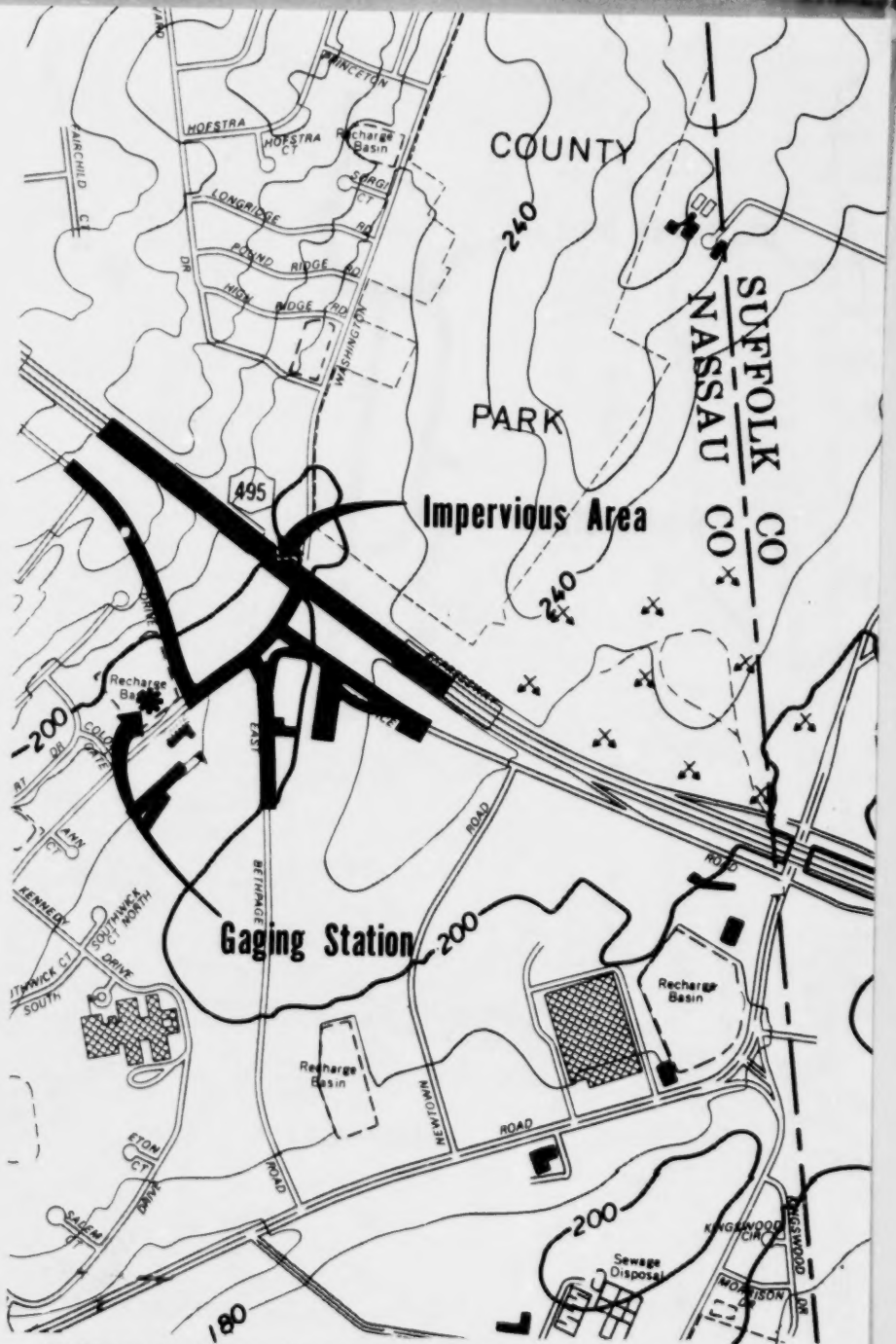
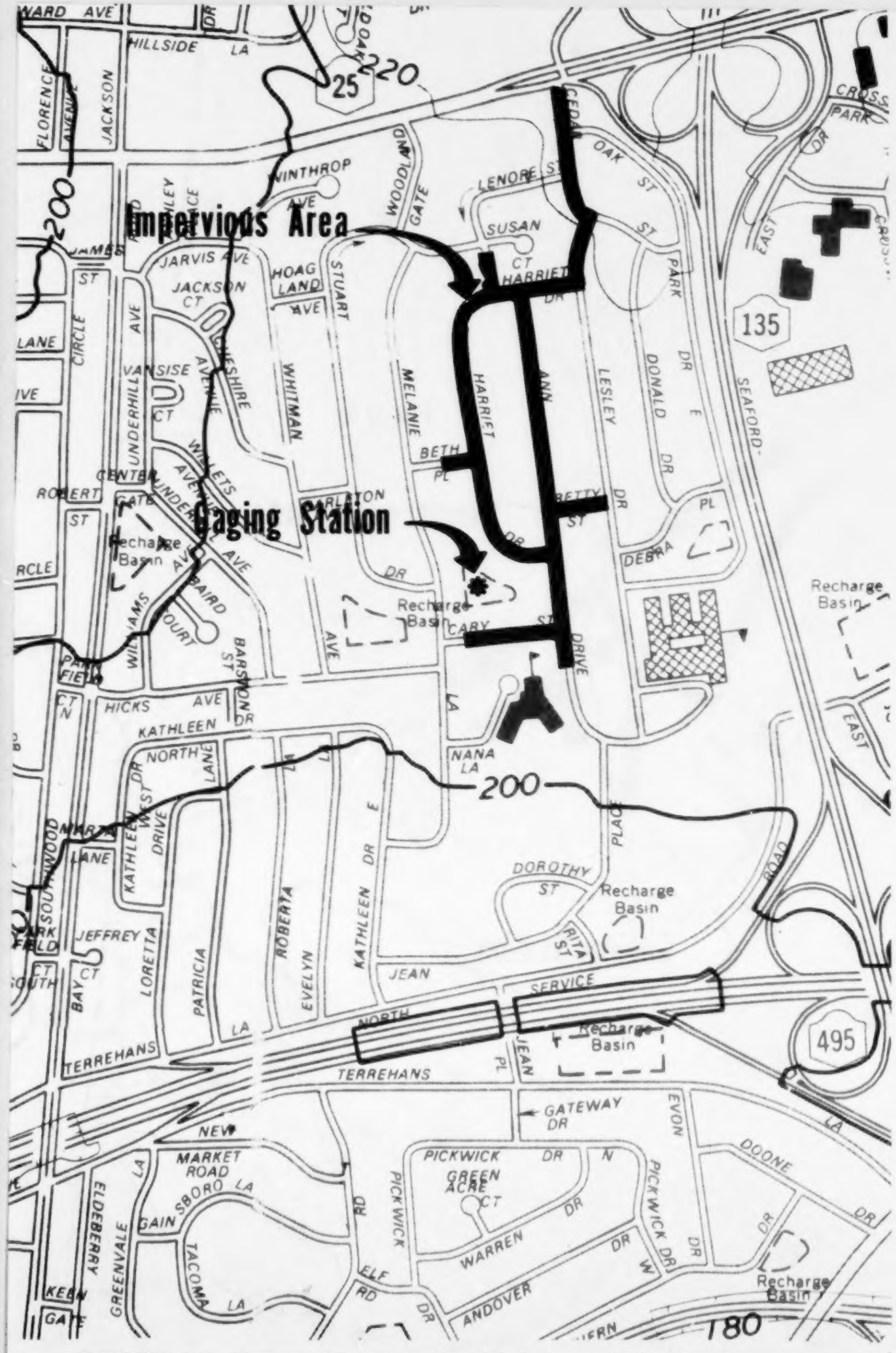


FIGURE 2-3.4 *Topographic map and aerial photograph of drainage area at Plainview*



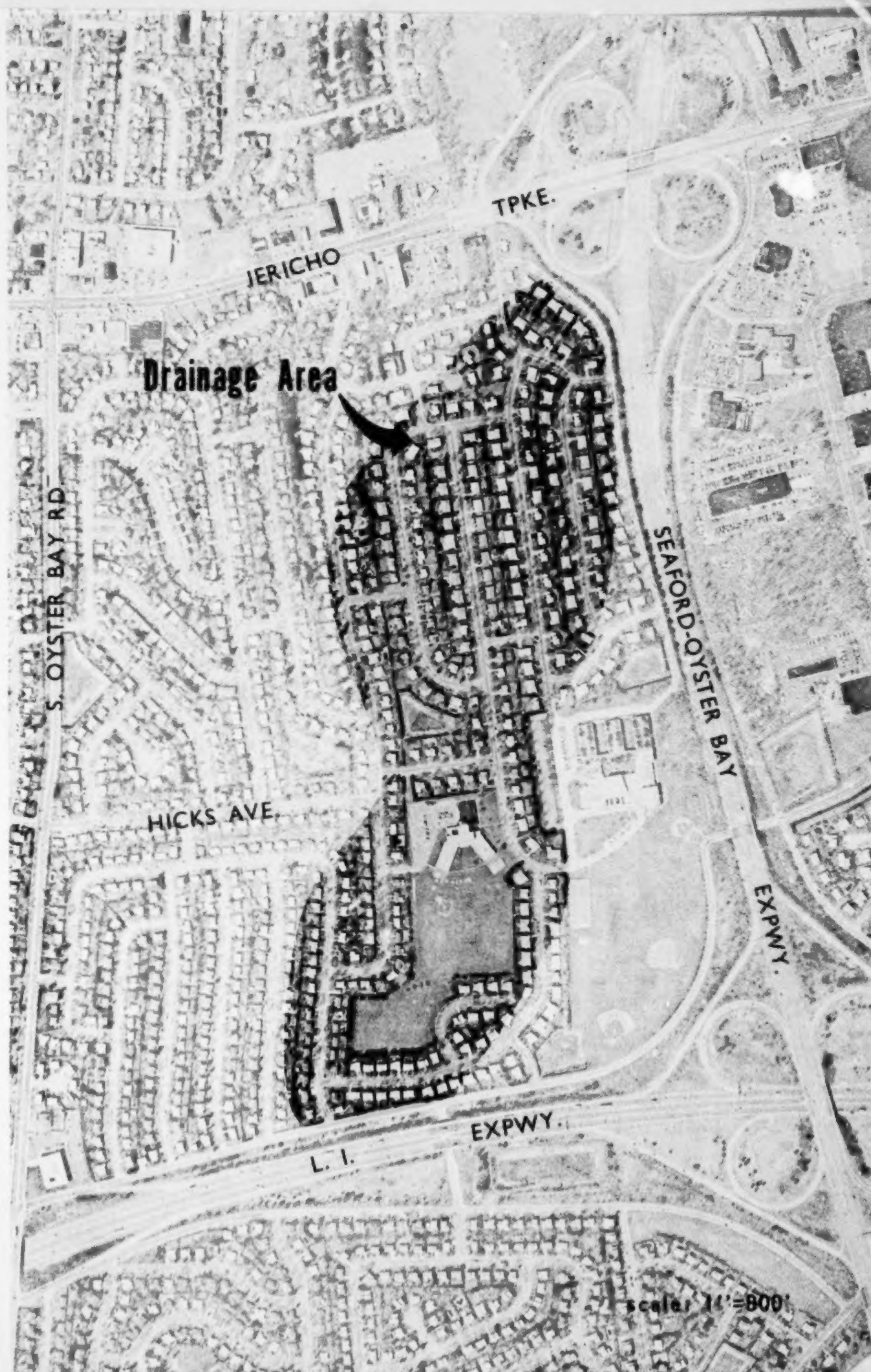


FIGURE 2-3.5 *Topographic map and aerial photograph of drainage area at Syosset*

2.1.2 Huntington. The recharge basin at Huntington (Figure 2-3.2) receives runoff from 39.2 acres of a large shopping center and the adjacent parking lot. The parking lot is paved with asphalt and is curbed. The basin floor occupies about 0.5 acres and is underlain by sand and gravel. Vegetation in this basin is sparser than in the others, consisting mainly of grass and weeds. There is no relief in the drainage area.

Most recharge basins on Long Island do not hold water longer than one to two days after a storm event. However, most basins that drain parking areas become clogged with oil and therefore contain water most, if not all, of the time. Although the basin at Huntington is clogged, stormwater runoff exfiltrates through the walls of the basin above the impermeable layer, enabling the basin to effectively recharge as much runoff as a basin that is not clogged.

2.1.3 Laurel Hollow. The recharge basin at Laurel Hollow (Figure 2-3.3) drains approximately 100 acres of low density residential area. Within this area, newly-constructed one-family houses are situated on lots of one or more acres. The basin was constructed recently (1979) and therefore has a bottom consisting of bare soil underlain by sand and gravel. The basin floor occupies about 0.6 acres.

Roads in the drainage area are two lanes wide, paved with asphalt and curbed in most places. Topographic relief is about 160 feet, which is the greatest relief of the five drainage basins under study.

2.1.4 Plainview. The recharge basin at Plainview (Figure 2-3.4), constructed in 1956, receives runoff from a major highway, the Long Island Expressway, and its service road. Of the 190 acres of topographic drainage area, 11.9 acres is the contributing area, consisting of a six-lane concrete highway, two-lane asphalt service roads, and a few driveways. The highway is curbed on both sides; the service road is not. Topographic relief in the drainage area is about 60 feet.

The basin floor occupies approximately 1 acre. It is underlain by sand and gravel and is covered by thick vegetation including grass, weeds, bushes, and some trees.

2.1.5 Syosset. The recharge basin at Syosset (Figure 2-3.5) drains approximately 28.2 acres of medium density residential area containing single-family houses situated on quarter-acre plots. The basin was constructed in 1957. Its floor occupies about 0.3 acres and is underlain by sand and gravel. Thick vegetation, including weeds, grass, and bushes, is present in the basin.

Roads in the drainage area are two lanes wide, paved with asphalt, and curbed. Topographic relief within the drainage area is less than 20 feet.

2.2 SAMPLING PROGRAM

The Long Island 208 study indicated that recharge basins may furnish an avenue for pollutants in stormwater runoff to reach the groundwater reservoir. The report by Weston (1977) estimated the annual load of pollutants to the groundwater from a limited number of stormwater runoff and groundwater samples. The groundwater component of the Nationwide Urban Runoff Program was designed to collect a large quantity of storm-related data in order to better define the impact of stormwater runoff on the quality of groundwater beneath Long Island's recharge basins. The five recharge basins described in the previous section were instrumented to collect precipitation, stormwater inflow into the basins, and stormwater that infiltrated to the water table to become groundwater.

2.2.1 Equipment. A schematic diagram of the instrumentation at each of the five sites is shown in Figure 2-4.

Precipitation was measured by a tipping bucket rain gage manufactured by Weathertronics, Inc., and recorded on 16 channel digital tape at five-minute intervals by a Stevens recorder. A precipitation sample was collected in a large plastic lined bucket placed outside the instrument housing for the duration of the storm. In this way, information on precipitation quantity, quality, and intensity was collected during each storm event.

Stormwater inflow to the recharge basins was measured by a Marsh-McBirney Velocity-Modified Flow Meter, model 250, and was recorded on 16-channel digital tape at five-minute intervals by a Stevens recorder. The flow rate was also recorded on a seven day circular chart that measures flow as a percentage of a user-determined maximum. This device is an integral part of the flow meter.

The stormwater was sampled from the sewer line by a Manning S-6000 Stationary Discrete Sampler. This sampler draws one liter of water through a vacuum line and discharges it into bottles in an attached refrigerated compartment. The sampler can be programmed to collect samples automatically at predetermined volume or time intervals, or it can be activated manually. This equipment allowed for the collection of data on total flow volume, flow rate, and stormwater quality.

A well adjacent to each recharge basin was equipped with a Stevens Type F water-level recorder that indicated when the stormwater reached the water table. Subsequent pumping and/or bailing of the well provided samples for water quality analysis.

2.2.2 Collection Procedures. The general procedure for collecting stormwater runoff samples for standard chemical analysis (Table 2-2) was as follows. The first sample was collected when flow first appeared in the sewer line and registered on the circular flow chart. Subsequent samples were collected at 10-, 20-, 30-, and 60-minute intervals. Hourly samples were collected thereafter when the flow was continuous. During intermittent flow, an attempt was made to collect samples near hydrograph peaks.

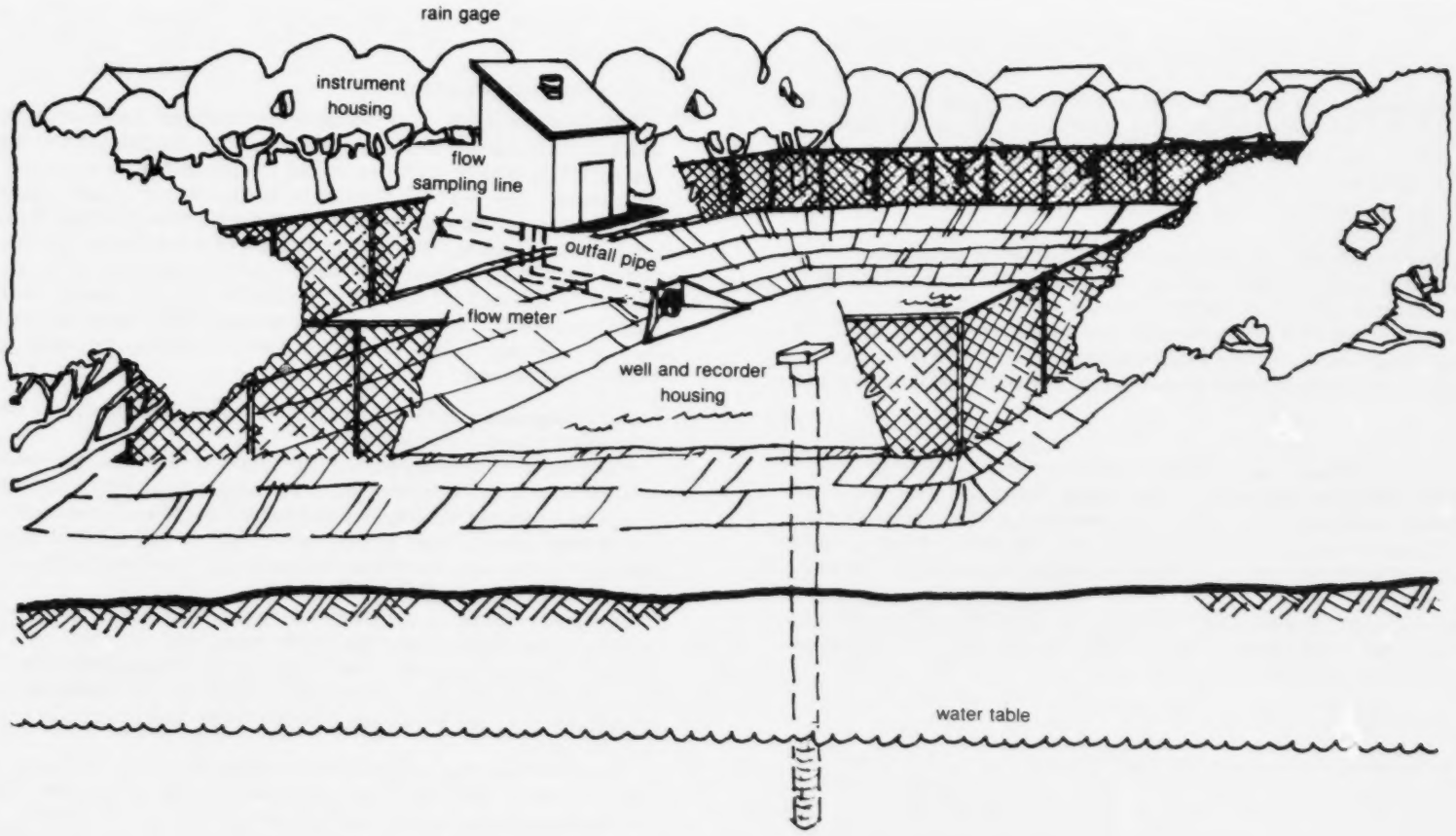


FIGURE 2-4 *Schematic diagram of instrumentation at each recharge basin*

Stormwater samples to be analyzed for bacteria were collected on the same schedule outlined above, but were collected manually using sterile bottles. They were delivered to the Nassau County Department of Health laboratory within hours after the cessation of flow.

Groundwater samples were collected in one-liter pretreated glass bottles, one or two days after the rainfall event. The well was first pumped for a minimum of 15 minutes using a submersible pump. Bacteriological samples were collected last.

All samples other than bacteriological were sent to the U.S. Geological Survey Central Laboratory in Doraville, Georgia. All analysis results were entered into the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and were later transferred to STORET, EPA's computer data base.

During this study, one stormwater and two groundwater samples were collected at each site (except Centereach) for analysis for EPA-designated Priority Pollutants. At Centereach, one stormwater and one groundwater sample were collected. A list of the compounds included in the category of Priority Pollutants is presented in Table 2-3.

The stormwater samples were collected manually, using a stainless steel vessel, and were poured into one-liter pretreated glass bottles with teflon seals. The grab samples were composited in the laboratory.

One one-liter sample was collected for every 2,000 gallons of stormwater inflow. Therefore, the first 32,000 gallons of stormwater runoff into the basins were represented by a sample of 16 liters. Runoff in excess of 32,000 gallons was not sampled.

Table 2-2

STANDARD CHEMICAL ANALYSIS

Arsenic Dissolved
Arsenic Total
BOD (Biochemical Oxygen Demand)
Cadmium Dissolved
Cadmium Suspended
Cadmium Total
Calcium Dissolved
Carbon Organic Dissolved
Carbon Organic Suspended
Chloride Dissolved
Chromium Dissolved
Chromium Suspended
Chromium Total
Color
Digestion HCl, Water
Fluoride Dissolved
Hardness Total
Lead Dissolved
Lead Suspended
Lead Total
Magnesium Dissolved
Metals Dissolved, Chelation Extraction
Metals Total, Chelation Extraction
Nitrogen Dissolved, NO_2 + NO_3 -N
Nitrogen Dissolved, NH_4 as N
Nitrogen Dissolved, NH_4 + Organic -N
Nitrogen Total, NH_4 + Organic -N
Nitrogen Dissolved, NH_4 as NH_4
pH Field
pH Lab
Phosphorus Dissolved, Orthophosphate as P
Phosphorus Dissolved, Orthophosphate -PO_4
Potassium Dissolved
Potassium 40, Dissolved, PCI/1
SAR (Sodium Absorption Ratio)
Sodium Dissolved
Sodium Percent
Specific Conductance Field
Specific Conductance Lab
Sulfate Dissolved
Turbidity (NTU) EPA
Water Temperature (°C)

The stormwater sample was sent as a flow-weighted composite, while the groundwater sample was a grab sample. These were packaged and preserved as recommended in *Monitoring of Toxic Pollutants in Urban Runoff: A Guidance Manual*, prepared by Versar, Inc., for EPA (1980).

2.2.3 Data Storage. Each sampling site was assigned a station identification number consisting of fifteen digits. The first thirteen digits represent the latitude and longitude of the sampling location. The last two digits, also called the sequence number, indicate the type of sample collected at that location, such as stormwater, precipitation, or groundwater. All data pertaining to stormwater, whether flow or water quality, use the same station number.

The station numbers used in this study are listed in Table 2-4. All data are stored in the U.S. Geological Survey's WATSTORE.

Table 2-3
EPA PRIORITY POLLUTANTS.

BASE/NEUTRAL COMPOUNDS

acenaphthene
benzidine
1,2,4-trichlorobenzene
hexachlorobenzene
hexachloroethane
bis (2-chloroethyl) ether
2-chloronapthalene
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
3,3'-dichlorobenzidine
2,4-dinitrotoluene
2,6-dinitrotoluene
1,2-diphenylhydrazine
(as azobenzene)
fluoranthene
4-chlorophenyl phenyl ether
4-bromophenyl phenyl ether
bis (2-chloroisopropyl) ether
bis (2-chloroethoxy) methane
hexachlorobutadiene
hexachlorocyclopentadiene
isophorone
naphthalene
nitrobenzene
N-nitrosodimethylamine
N-nitrosodiphenylamine
N-nitrosodi-n-propylamine
bis (2-ethylhexyl) phthalate
butyl benzyl phthalate
di-n-butyl phthalate
di-n-octyl phthalate
diethyl phthalate
dimethyl phthalate
benzo (a) anthracene
benzo (a) pyrene
3,4-benzofluoranthene
benzo (k) fluoranthene
chrysene

acenaphthylene
anthracene
benzo (ghi) perylene
fluorene
phenanthrene
dibenzo (a, b) anthracene
indeno (1,2,3-cd) pyrene
pyrene
2,3,7,8-tetrachlorodibenzo-p-dioxin

ACID COMPOUNDS

2,4,6-trichlorophenol
p-chloro-m-cresol
2-chlorophenol
2,4-dichlorophenol
2,4-dimethylphenol
2-nitrophenol
4-nitrophenol
2,4-dinitrophenol
4,6-dinitro-o-cresol
pentachlorophenol
phenol

Table 2-3 (Continued)

VOLATILES

acrolein
acrylonitrile
benzene
carbon tetrachloride
chlorobenzene
1,2-dichloroethane
1,1,1-trichloroethane
1,1-dichloroethane
1,1,2-trichloroethane
1,1,2,2-tetrachloroethane
chloroethane
bis (chloromethyl) ether
2-chloroethylvinyl ether
chloroform
1,1-dichloroethylene
1,2-trans-dichloroethylene
1,2-dichloropropane
1,3-dichloropropylene
ethylbenzene
methylene chloride
methyl bromide
bromoform
dichlorobromomethane
trichlorofluoromethane
dichlorodifluoromethane
chlorodibromomethane
tetrachloroethylene
toluene
trichloroethylene
vinyl chloride

PESTICIDES

aldrin
dieldrin
chlordane
4,4'-DDT
4,4'-DDE
4,4'-DDD
α-endosulfan
β-endosulfan
endosulfan sulfate
endrin
endrin aldehyde
heptachlor
heptachlor epoxide
α-BHC
β-BHC
γ-BHC
δ-BHC
PCB-1242
PCB-1254
PCB-1221
PCB-1232
PCB-1248
PCB-1260
PCB-1016
toxaphene

Table 2-4
STATION NUMBERS USED

Site	Station Number	Sample Type
Centereach	405135073055101	stormwater
	405135073055102	groundwater
	405135073055103	groundwater
	405135073055104	precipitation
Huntington	404932073243701	stormwater
	404932073243702	groundwater
	404932073243704	precipitation
Laurel Hollow	405124073292601	stormwater
	405124073292602	groundwater
	405124073292604	precipitation
Plainview	404713073273001	stormwater
	404713073273002	groundwater
	404713073273004	precipitation
Syosset	404815073294601	stormwater
	404815073294603	groundwater
	404815073294604	precipitation

2.3 CHARACTERISTICS OF SAMPLED STORMS

A total of 46 storm events were sampled at the five recharge basins. The choice of particular storm events was based on seasonal distribution and an attempt to sample a variety of storm types.

Table 2-5 shows the distribution of storms sampled by season and by site. Fewer storms were sampled during the summer because thunderstorms are typically hard to predict and are often of short duration.

Table 2-6 summarizes some of the important characteristics of each storm event sampled. These characteristics include precipitation duration, total precipitation, maximum intensity (maximum precipitation during a 15 minute period), total runoff, and number of antecedent dry days. (A dry day is defined as a day with less than 0.1 inches of precipitation.)

The storm events sampled vary widely in duration and total precipitation. Storm duration varies from 2 hours to 26 hours, and precipitation varies from 0.20 inches to 4.84 inches. During the study period, many storms occurred that were of shorter duration and had less precipitation, but experience has shown that an event with less than 0.2 inches of continuous precipitation will not produce significant runoff.

Table 2-5
NUMBER OF STORM EVENTS SAMPLED PER SITE, BY SEASON

Season	Site: Centereach	Huntington	Laurel Hollow	Plainview	Syosset	Total
autumn	0	2	3	5	3	13
winter	2	4	3	4	0	13
spring	4	5	2	0	3	14
summer	0	1	1	1	3	6
Total	6	12	9	10	9	46

Table 2-6

STORM CHARACTERISTICS

Date	Site	Duration (hr)	Precipitation (in)	Maximum Intensity (in/15 min)	Total Runoff (ft^3)	Antecedent Dry Days ($\leq$.1 in)
9-18-80	Plainview	7	0.64	0.12	1,390	2
	Huntington	7	0.59	0.08	3,330	2
10-25-80	Syosset	7	1.67	0.12	12,300	5
	Huntington	9	1.36	0.12		5
	Plainview	8	1.51	0.11	27,600	5
11-18-80	Laurel Hollow	7	0.93	0.09	2,140	7
	Plainview	7	0.78	0.08	21,800	7
11-24-80	Laurel Hollow	11	1.48	0.33	7,570	5
	Plainview	11	1.37	0.17	55,100	5
12-9-80	Laurel Hollow	6	0.20	0.04	121	1
	Plainview	6	0.20	0.04	112	1
12-30-80	Plainview[a]					1
2- 1,2-81	Laurel Hollow	18	0.85	0.06	6,070	14
	Plainview	6	0.75	0.06	26,500	14
2-11-81	Plainview	7	0.52	0.23	28,300	2
2- 19,20 -81	Huntington	22	1.49	0.15	17,200	6
	Laurel Hollow	22	1.80	0.06	[b]10,300	6
2- 23,24 -81	Huntington	7	0.75	0.05	6,860	1
	Laurel Hollow	8	0.82	0.13	3,940	1

Table 2-6 (Continued)
STORM CHARACTERISTICS

Date	Site	Duration (hr)	Precipitation (in)	Maximum Intensity (in/15 min)	Total Runoff (ft^3)	Antecedent Dry Days ($\leq$.1 in)
3-30-81	Huntington	6	[b].49		[b]9,230	12
	Laurel Hollow	6	0.40	0.04	1,000	12
4-14-81	Huntington	8	[b]1.03		4,610	4
	Syosset	9	1.04	0.09	10,400	4
4-23-81	Huntington	4	0.80	0.32	650	8
4- 23,24 -81	Syosset	8	0.98	0.32	12,300	8
5- 11,12 -81	Huntington	[b]12	[b].27		10,500	6
5-11-81	Laurel Hollow	13	0.26	0.04	611	6
5-29-81	Huntington		[b].86		21,900	11
	Syosset	6	0.44	0.15	[b]11,400	11
7-3-81	Laurel Hollow	2	0.88	0.26	[b]3,040	1
7-20-81	Huntington	[b]3	[b].95		15,400	13
	Syosset	[b]13	[b].85		11,200	13
7-29-81	Syosset	2	0.18	0.09	1,640	1
9-8-81	Plainview	3	0.69	0.23	21,800	7
9- 15,16 -81	Huntington	[b]24	1.65		112,000	6
	Syosset	26	1.77	0.10	31,600	6
12-1-81	Syosset	11	1.12	0.12	33,900	10
12- 15,16 -81	Syosset	13	1.98	0.04	27,600	0.4
1-23-82	Huntington[c]	5	1.33	0.18	56,900	
2- 2,3-82	Plainview	8	1.32	0.08	80,600	1
3-4-82	Centereach	5	0.84	0.12	27,500	12
3- 16,17 -82	Centereach	3	0.65	0.07	7,750	2
4-26-82	Centereach	6	[b]1.89		[b]31,800	8
6- 1,2 -82	Centereach	4	1.55	0.25	57,700	2
6-5-82	Centereach	16	4.84	0.24	191,000	2
6-16-82	Centereach	2	0.45	0.18	19,100	1

[a] equipment failure
[b] estimated
[c] including snow melt

Because storm characteristics vary so widely, extreme caution must be used in making comparisions between storms.

Table 2-7 lists the number and type of all samples collected during the study as part of the conventional (non-priority pollutant) sampling program. There are 750 in all. For each storm at each site, precipitation was sampled for standard chemical analyses (Table 2-2), and stormwater runoff and groundwater were sampled both for bacteria and standard chemical analysis. In addition, the pond at Centereach was sampled for bacteria several days after a storm, to obtain information on the effect of pond residence time on the bacteria count. Bacteria analyses included determinations of total coliforms, fecal coliforms, and fecal streptococci.

Table 2-7
STORMWATER RUNOFF SAMPLING PROGRAM: SOURCE OF SAMPLE AND TYPE OF ANALYSES PERFORMED

	SITE															
	Huntington			Centereach				Laurel Hollow			Syosset			Plainview		
Source: Date	P	RO	GW	P	RO	GW	PD	P	RO	GW	P	RO	GW	P	RO	GW
9-18-80	1S	5B, 5S	1B,1S											1S	4B, 5S	1B,1S
10-25-80	1S	7B, 7S	1B,1S								1S	7B, 7S	1B,1S	1S	9B, 9S	1B,1S
11-18-80								1S	10B,10S	1B,2S				1S	9B, 9S	1B,2S
11-24-80								1S	10B, 9S	1B,2S				1S	7B, 9S	1B,2S
12-09-80								1S	2B, 2S	1B,2S				1S	2B, 2S	1B,2S
12-30-80														1S	3B, 3S	2S
02-02-81								1S	15B,10S	2B,1S				1S	12B,12S	2B,1S
02-11-81														1S	9B, 9S	2B,2S
02-20-81	1S	13B,13S	2B,2S					1S	12B,15S	2B,2S						
02-23-81	1S	7B, 7S	1B,2S					1S	9B, 9S	2B,2S						
03-30-81	1S	7B, 7S	1B,1S					1S	6B, 6S	1B,1S						
04-14-81	1S	6B, 6S	1B,1S								1S	7B, 7S	1B,1S			
04-23-81	1S	6B, 6S	1S								1S	8B, 8S	1S			
05-11-81		5B,5S,5M	2B,2S					1S	4B, 4S	2B,2S						
05-29-81	1S	8B, 9S									1S	5B, 5S				
07-03-81								1S	2S							
07-20-81	1S	6B, 6S	1B,1S								1S	8B, 8S	1S			
07-29-81											1S	3B, 3S				
09-08-81														1S	6B, 6S	1S
09-15-81	1S	5B, 5S	1B,1S								1S	6B, 6S	1B,1S			
12-01-81											1S	7B, 7S	1B,1S			
12-15-81											1S	12B, 5S	1B,1S			
01-23-82	1S	7S														
02-02-82														1S	12B,12S	1B,1S
03-04-82					6B,5S	1B,1S										
03-16-82				1S	4B,3S	1B										
04-26-82				1S	7B,7S	1B,1S	5B									
06-01-82					6B,6S	1B,1S	1B									
06-05-82				1S	8S	1S										
06-16-82					4B,4S	1B,1S	1B									

Explanation: S, standard chemical analysis (see table 2-2); B, bacteria analysis; M, metals analysis; P, precipitation; RO, stormwater runoff; GW, groundwater; PD, pond.

A special metals analysis of five stormwater runoff samples collected from the recharge basin at Huntington during the storm of 5-11-81 was also performed. The samples were analyzed for concentrations of 29 metals. The results are included in Versar, Inc. (1982).

Table 2-8 lists the priority pollutant samples collected during the study. There are five stormwater samples, one for each site. There are nine groundwater samples, two for each site except Centereach, where only one groundwater sample was collected.

Table 2-8
PRIORITY POLLUTANTS SAMPLING PROGRAM

Site	Date	Sample Type
Centereach	4-26-82	stormwater
	4-27-82	groundwater
Huntington	3-30-81	stormwater
	5-7-81	groundwater
	9-28-81	groundwater
Laurel Hollow	3-30-81	stormwater
	5-7-81	groundwater
	9-28-81	groundwater
Plainview	2-11-81	stormwater
	5-7-81	groundwater
	9-28-81	groundwater
Syosset	4-14-81	stormwater
	5-7-81	groundwater
	9-28-81	groundwater

2.4 ANALYTICAL PROCEDURES

2.4.1 Standard Chemical Analysis. Samples collected for standard chemical analysis (see Table 2-2) were kept chilled at all times, including during transportation from the field to the laboratory. In the laboratory, each one-liter sample was split into ten parts, from which the analyses were performed. Split samples were packed with ice and sent to the U.S. Geological Survey Laboratory in Doraville, Georgia, for analysis.

2.4.2 Bacteria. Bacteriological samples were kept chilled in the field and during transportation to the Nassau County Health Department Laboratory, where they were analyzed for total coliform, fecal coliform, and fecal streptococci bacteria within 24 hours of collection.

2.4.3 Priority Pollutants. Groundwater and stormwater samples collected for priority pollutant analysis (see Table 2-3) were sent overnight to one of a number of EPA-approved laboratories across the United States. Stormwater runoff samples were submitted as flow-weighted composites. Samples were collected and preserved in accordance with *Monitoring of Toxic Pollutants in Urban Runoff: A Guidance Manual*, prepared by Versar, Inc., for EPA (1980).

2.5 ANALYSIS OF DATA

2.5.1 Runoff/Precipitation Relationship. Long Island's soil in general consists of medium to fine grained sand, and therefore has a high infiltration rate. Seaburn (1969) showed that for the pre-urban period (1937-43) at the East Meadow Brook drainage basin in south central Nassau County, the ratio of runoff to precipitation was 5 to 6 percent. This ratio indicates that there was little or no runoff during most storm events before urbanization.

In Table 2-9 the runoff/precipitation ratio is computed for all sampled storm events. The runoff volume shown in cubic feet was divided by the contributing impervious surface area to obtain the runoff in inches. The contributing impervious surface area was used instead of the topographic drainage area because

1. the topographic drainage area often does not coincide with the storm sewer drainage network and
2. most runoff during a typical storm event can be accounted for by the amount of precipitation falling on impervious surfaces.

Table 2-10 shows the median and range of the runoff/precipitation ratio for each of the five sampling sites. A ratio of 100 percent or less indicates that all runoff can be accounted for by precipitation that falls directly on impervious surfaces. A ratio greater than 100 percent indicates that there is runoff from precipitation that falls on both pervious and impervious surfaces. The median runoff/precipitation ratios in Table 2-10 show that most runoff into the recharge basins can be accounted for by the amount of rain that falls directly on the impervious surfaces. In other words, there is no runoff from unpaved areas.

Theoretically, the Huntington site should always have a runoff/precipitation ratio of 100 percent because its drainage area is 100 percent impervious.

Table 2-9

PRECIPITATION, RUNOFF, and RUNOFF/PRECIPITATION RATIO FOR SAMPLED STORMS

	BASIN											
	Centereach				Huntington				Laurel Hollow			
Date	Precipitation (in)	Runoff (ft^3)	Runoff (in)	Runoff/Precipitation (percent)	Precipitation (in)	Runoff (ft^3)	Runoff (in)	Runoff/Precipitation (percent)	Precipitation (in)	Runoff (ft^3)	Runoff (in)	Runoff/Precipitation (percent)
9-18-80					0.59	3,330	0.02	4				
10-25-80												
11-18-80						———			0.93	2,140	0.14	14
11-24-80												
12-9-80												
										——	——	
2-1-81									0.85	6,070	0.36	42
2-11-81												
2-19,20												
-81					1.49	17,100	0.12	8	1.80	10,300	0.61	34
2-23-81					0.75	6,860	0.05	7	0.82	3,930	0.23	28
3-30-81					0.49*	9,230	0.07	14	0.40	1,000	0.06	15
4-14-81					1.03*	4,610	0.03	3				
4-23-81					0.73*	650	0.05	0.7				
5-11-81					0.27*	10,500	0.07	26	0.26	610	0.03	12
5-29-81					0.86	21,900	0.07	8				
7-3-81									0.88	3,040	0.18	20
7-20-81					0.95	15,400	0.11	12				
7-29-81												
9-8-81												
9-15-81					1.65	112,000	0.79	48				
12-1-81												
12-15-81												
1-21-82					1.33	67,600	0.48	36				
2-2-82												
3-4-82	0.84	28,900	1.6	191								
3-16-82	0.65	7,750	0.37	57								
4-26-82	1.89*	31,800	1.5	79								
6-1,2												
-82	1.55	57,700	2.7	174								
6-5-82	4.84	191,000	9.0	186								
6-16-82	0.45	19,100	0.91	202								

*Syosset precipitation record

Table 2-9 (Continued)

PRECIPITATION, RUNOFF, and RUNOFF/PRECIPITATION RATIO FOR SAMPLES STORMS

Date	Plainview BASIN				Syosset BASIN			
	Precipitation (in)	Runoff (ft^3)	Runoff (in)	Runoff/Precipitation (percent)	Precipitation (in)	Runoff (ft^3)	Runoff (in)	Runoff/Precipitation (percent)
9-18-80	0.64	1,390	0.03	5	1.67	12,300	0.53	32
10-25-80	1.51	27,600	0.63	42				
11-18-80	0.78	21,800	0.51	65				
11-24-80	1.37	55,100	1.27	93				
12-9-80	1.48	7,570	0.44	30				
		——	——					
2-1-81	0.75	26,500	0.62	83				
2-11-81	0.52	28,300	0.66	127				
2-19,20 -81								
2-23-81								
3-30-81								
					1.07	10,400	0.46	43
4-14-81					0.98	9,790	0.43	44
4-23-81								
5-11-81					0.44	11,400	0.50	114
5-29-81								
7-3-81								
					0.85	11,200	0.50	59
7-20-81					0.18	1,640	0.07	39
7-29-81								
9-8-81	0.69	21,800	0.50	73	1.77	31,600	1.40	79
9-15-81					1.79	33,900	1.48	83
12-1-81								
					1.98	27,600	1.21	61
12-15-81								
1-21-82								
2-2-82	1.32	80,600	1.86	1.4				
3-4-82								
3-16-82								
4-26-82								
6-1,2 -82								
6-5-82								
6-16-82								

Table 2-10
MEDIAN AND RANGE OF RUNOFF/PRECIPITATION RATIO, IN PERCENT

Basin	Minimum	Median	Maximum
Centereach	57	180	202
Huntington	0.7	11	48
Laurel Hollow	13	24	42
Plainview	5	75	180
Syosset	32	60	114

Table 2-10, however, shows very low ratios for the Huntington basin. This is probably due to two factors: (1) occasional inaccurate flow data caused by reverse flow in the inflow pipe where the electromagnetic flow sensor is located; and (2) possible exfiltration through manholes and storm sewer lines.

If the Huntington basin is not considered, the lowest median runoff/precipitation value (24) is exhibited at Laurel Hollow, the low density residential area. The value is higher (60) at Syosset, the medium density residential area, and still higher (75) at Plainview, the predominantly paved highway area.

The strip commercial area at Centereach exhibits very high runoff/precipitation values. These numbers may be biased by unaccounted for rooftop, parking, and side-steet areas that may drain into the recharge basin. In addition, three of the six storms sampled at Centereach had precipitation in excess of 1.5 inches. (See Table 2-6 for detailed storm characteristics.) During such storms, runoff from pervious surfaces would be significant.

Figure 2-5 is a log-log plot of precipitation versus runoff for each of the five sampling sites. Despite a rather large degree of scatter, it is apparent that the data points tend toward a straight-line relationship. This relationship is especially good for Laurel Hollow and Centereach. The scatter may be due to variables such as seasonal effects, storm duration and intensity, and number of antecedent dry days. The small number of data points also contributes to the poor correlation.

Using one inch of precipitation as an index, the following amounts of runoff are derived from the graphs in Figure 2-5:

Centereach	1.50 inches
Huntington	0.13 inches
Laurel Hollow	0.28 inches
Plainview	0.82 inches
Syosset	0.60 inches

These data correlate well with the median values given in Table 2-10. They show that for one inch of precipitation, all of the runoff (with the exception of the Centereach site, for the reasons outlined above) can be accounted for by the precipitation that falls directly on impervious surfaces.

2.5.2 Stormwater Quality

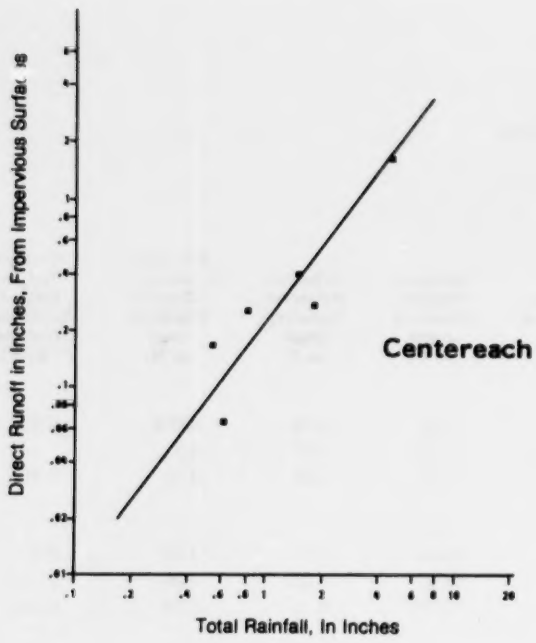
2.5.2.1 Standard Chemical Analysis. During each storm event, stormwater inflow was collected for analysis for the suite of water quality parameters listed in Table 2-2, as well as the three bacterial indicators. These data are stored in the U.S. Geological Survey WATSTORE and EPA STORET computer data bases.

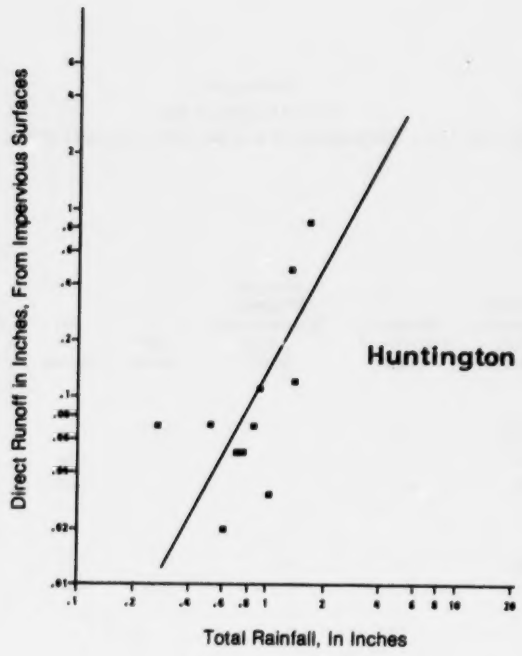
A statistical summary of selected water quality parameters for all storm events during the period of record for each of the five stations is shown in Table 2-11. The data indicate that, in general, concentrations of most of the chemical constituents analyzed for are low. In most cases they fall within the standards for potable water.

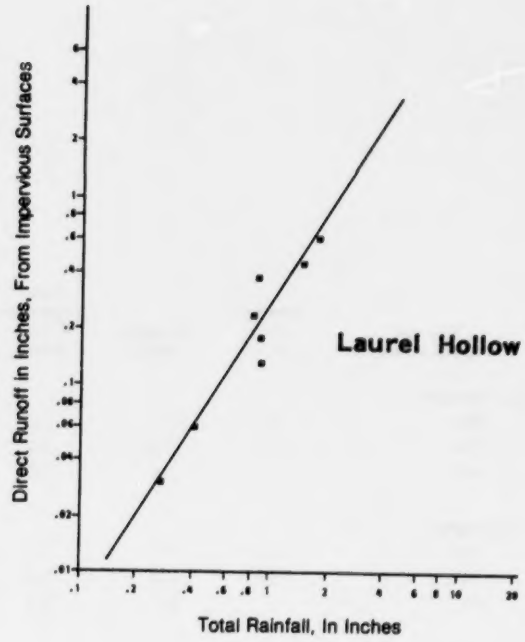
There are several notable exceptions to this generalization that can be related to specific land uses and seasonal effects. For example, the Plainview basin, which receives stormwater runoff from a major highway, shows a median lead concentration of 275 micrograms per liter (µg/l) and a high of 3,300 µg/l. Chloride concentrations were higher during the winter months, ranging up to a maximum of 1,100 mg/l at Huntington, because of the use of salt for road deicing.

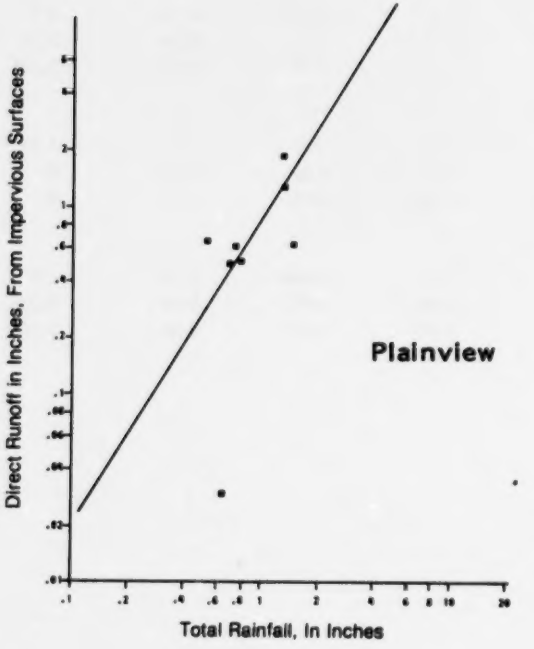
Typical hydrographs (discharge versus time), hyetographs (rainfall versus time), and pollutographs (concentration versus time) for each sampling site are shown in Figures 2-6 through 2-10. These graphs show the near simultaneous nature of the rainfall-runoff response in storm-sewered areas. The pollutographs show that peak constituent concentrations (in this case, lead, chromium, chloride, and total nitrogen) are generally associated with the first runoff peak. Additional peaks in runoff usually do not cause corresponding peaks in constituent concentrations. This is probably due to the near complete removal of pollutants from the streets with the first major surge of water. During a storm of long duration (16 hours) sampled at the Centereach site on June 5, 1982, the water quality of the stormwater runoff gradually approached the quality of the precipitation. Therefore, no attempt was made here to correlate discharge with constituent concentrations, because no physical relationship exists between the two.

2.5.2.2 Priority Pollutants. The results of priority pollutant analysis are summarized in Tables 2-12 and 2-13. Table 2-12 shows the concentrations of the acid and base/neutral compounds that were detected in the stormwater and groundwater samples collected especially for priority pollutant analysis. Table 2-13 shows the concentrations of the volatile compounds, phenols, and cyanide detected. Replicate samples were collected on each sampling day for purposes of quality assurance. These results are also included in the tables, as are occasional analyses of room air (in the analyzing laboratory) and deionized water blanks.









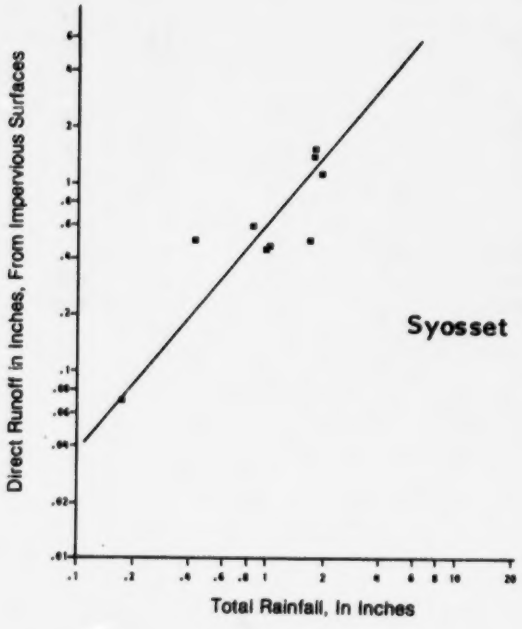


FIGURE 2-5 *Runoff/Precipitation relationship at Centereach, Huntington, Laurel Hollow, Plainview, and Syosset*

Table 2-11
MEDIAN VALUE ALL
STORMWATER (SW), GROUNDWATER (GW), AND PRECIPITATION (PR) DATA

Site and Sample Type	Temperature (C°)	Turbidity (NTU)	Color (Platinum-Cobalt Units)	Specific Conductance (μmhos)	Oxygen, Dissolved (mg/l)	Oxygen Demand, Biochemical, 5 Day (mg/l)	pH (units)	pH Lab (units)	Nitrogen Dissolved (mg/l as N)	Nitrogen, Organic Dissolved (mg/l as N)	Nitrogen, Ammonia Dissolved (mg/l as N)	Nitrogen, Ammonia + Organic Dissolved (mg/l as N)	Nitrogen, NH_4 + Organic Suspended Total (mg/l as N)
Centereach													
SW	5.5	27.0	15.0	55.0	—	—	6.75	6.7	2.9	0.86	0.08	0.965	0.200
GW	—	5.45	2.0	104	—	—	—	6.6	0.91	0.43	0.05	0.5	—
PR	—	2.4	1.5	15	—	—	—	5.85	1.2	0.46	0.08	0.78	0.15
Huntington													
SW	12.0	1.7	5.0	320	—	4.5	6.7	6.7	0.9	0.33	0.15	0.49	0.17
GW	13.0	0.9	1.0	217	—	1.0	5.4	6.1	6.3	0.20	0.020	0.28	0.015
PR	—	0.7	5.0	—	—	—	—	5.7	0.805	0.265	0.13	0.58	0.010
Laurel Hollow													
SW	9.0	13.0	30.0	60	—	7.0	7.0	6.7	1.0	0.44	0.075	0.55	0.7
GW	11.0	0.4	1.0	61	—	2.0	6.1	6.4	1.0	0.17	0.02	0.19	0.23
PR	10.0	0.4	5.0	60	—	—	6.6	5.7	0.29	0.13	0.04	0.155	0.005
Plainview													
SW	7.0	20.0	16.5	120	50.0	10.0	6.9	6.8	1.3	0.58	0.12	0.7	1.35
GW	10	0.4	0.0	200	—	2.5	6.55	6.8	1.3	0.20	0.02	0.24	0
PR	6.5	0.5	1.5	—	—	—	7.1	6.0	0.59	0.095	0.08	0.16	0
Syosset													
SW	19	3.6	15.0	58.5	—	9.0	6.9	6.4	1.35	0.60	0.090	0.76	0.6
GW	14	26.0	.5	104.0	—	1.0	5.1	6.0	2.55	0.38	0.02	0.39	0.035
PR	—	0.9	1.5	42.0	—	—	4.4	5.35	1.20	0.29	0.16	0.66	0.025

— data unavailable

Table 2-11 (Continued)
MEDIAN VALUE ALL
STORMWATER (SW), GROUNDWATER (GW), AND PRECIPITATION (PR) DATA

Site and Sample Type	Nitrogen, Ammonia + Organic Total (mg/l as N)	Nitrogen, $NO_2 + NO_3$ Dissolved (mg/l as N)	Phosphate, Ortho, Dissolved (mg/l as PO_4)	Phosphorus, Ortho, Dissolved (mg/l as P)	Carbon, Organic Dissolved (mg/l as C)	Carbon, Organic Suspended Total (mg/l as C)	Cyanide Total (mg/l as Cn)	Hardness (mg/l as $CaCO_3$	Calcium Dissolved (mg/l as Ca)	Magnesium, Dissolved (mg/l as Mg)	Sodium, Dissolved (mg/l as Na)
Centereach											
SW	1.15	0.42	0.06	0.02	6.4	5.6	—	12.0	3.5	0.69	3.5
GW	0.1	0.31	0.11	0.01	2.5	0.6	—	33.0	7.5	1.4	9.5
PR	0.595	0.105	0.09	0.015	2.7	0.7	—	1.0	0.205	0.095	0.3
Huntington											
SW	0.65	0.34	0.09	0.03	3.4	4.0	.011	12.0	3.7	0.7	40.0
GW	0.32	5.8	0.045	0.01	1.3	0.9	0.0	56.0	17.0	3.5	19.0
PR	0.67	0.26	0.09	0.020	3.5	2.0	—	2.5	0.49	0.255	1.75
Laurel Hollow											
SW	1.5	0.44	0.18	0.055	5.8	6.9	.02	14.5	4.3	0.8	3.3
GW	0.41	0.815	0.03	0.01	1.8	1.65	0.0	15.0	4.5	0.9	3.7
PR	0.195	0.16	0.045	0.01	1.05	0.7	—	2.0	0.30	0.10	1.1
Plainview											
SW	2.3	0.495	0.15	0.05	6.90	7.3	0.0	26.0	7.85	1.2	8.5
GW	0.15	0.82	0.03	0.01	2.40	0.90	0.0	40.0	9.0	3.6	27.0
PR	0.32	0.28	0.06	0.02	1.80	1.6	—	2.0	0.4	0.2	0.5
Syosset											
SW	1.35	0.340	0.280	0.090	6.3	5.1	0.0	15.0	3.7	1.25	1.5
GW	0.395	1.60	0.060	0.010	1.1	1.3	0.0	16.5	4.85	1.2	4.25
PR	0.645	0.415	0.090	0.030	2.6	1.6	—	2.0	0.50	0.185	0.95

— data unavailable

Table 2-11 (Continued)
MEDIAN VALUE ALL
STORMWATER (SW), GROUNDWATER (GW), AND PRECIPITATION (PR) DATA

Site and Sample Type	Sodium Adsorption Ratio	Potassium, Dissolved (mg/l as K)	Chloride, Dissolved (mg/l as Cl)	Sulfate Dissolved (mg/l as SO_4)	Fluoride, Dissolved (mg/l as F)	Arsenic Dissolved (µg/l as As)	Arsenic Suspended Total (µg/l as As)	Arsenic Total (µg/l as As)	Cadmium Dissolved (µg/l as Cd)	Cadmium Suspended Recoverable (µg/l as Cd)	Cadmium Total Recoverable (µg/l as Cd)	Chromium, Dissolved (µg/l as Cr)
Centereach												
SW	0.5	0.5	3.3	4.0	0.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
GW	0.8	1.65	8.1	11.0	0.1	1.0	—	1.0	1.0	0.0	1.0	1.0
PR	0.1	0.1	0.85	1.1	0.1	1.0	1.0	1.0	2.0	0.5	3.0	1.0
Huntington												
SW	5.8	0.5	71.5	6.55	0.1	0.0	0.0	0.0	0.0	0.0	1.0	2.0
GW	1.05	3.0	26.0	28.0	0.1	0.0	0.5	0.0	0.0	0.0	1.0	2.0
PR	0.5	0.3	3.0	3.05	0.1	0.0	0.0	0.5	0.0	0.0	1.0	1.5
Laurel Hollow												
SW	0.40	1.6	4.1	4.5	0.1	0.5	1.0	1.0	0.0	0.0	0.0	3.0
GW	0.40	.7	4.3	11.0	0.1	0.0	0.0	0.0	0.0	0.0	1.0	3.0
PR	0.40	0.15	1.70	1.55	0.1	0.0	0.0	0.0	0.0	.5	1.0	2.0
Plainview												
SW	1.1	2.3	10.0	11.0	0.10	1.0	1.0	1.5	1.0	0.0	1.0	2.0
GW	2.1	1.6	46.0	16.0	0.05	0.0	0.5	1.0	1.0	0.0	1.0	0.5
PR	0.3	0.2	2.6	1.65	0.05	0.0	0.0	1.0	0.0	0.0	1.0	1.0
Syosset												
SW	0.1	1.6	2.3	5.45	0.1	1.0	0.0	1.0	1.0	1.0	1.0	1.0
GW	0.5	1.0	7.3	7.05	0.1	0.0	1.0	1.0	2.5	2.5	8.5	1.0
PR	0.3	0.3	1.65	2.65	0.1	0.5	1.0	1.0	1.0	0.5	1.0	1.5

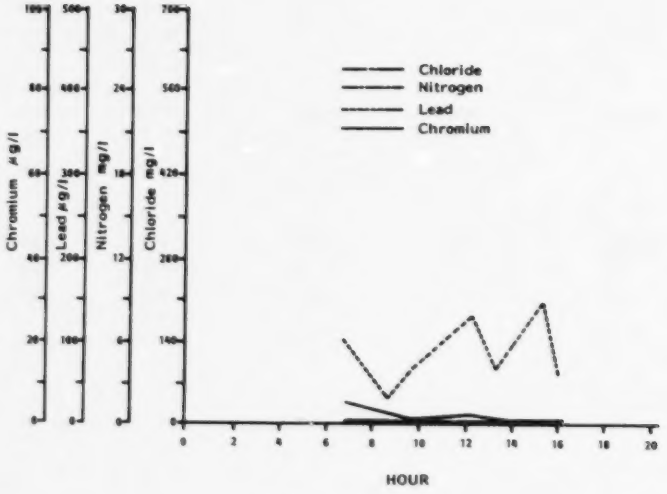
— data unavailable

Table 2-11 (Continued)
MEDIAN VALUE OF ALL STORMWATER (SW), GROUNDWATER (GW), AND PRECIPITATION (PR) DATA

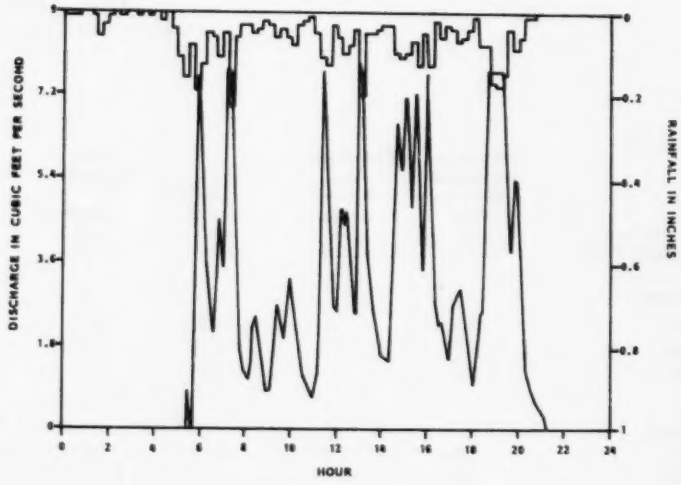
Site and Sample Type	Chromium, Suspended Recoverable (µg/l as Cr)	Chromium, Total Recoverable (µg/l as Cr)	Lead, Dissolved (µg/l as Pb)	Lead Suspended Recoverable (µg/l as Pb)	Lead, Total Recoverable (µg/l as Pb)	Coliform, Confirmed (MPN)	Coliform, Fecal EC Broth (MPN)	Streptotocci, Fecal (MPN)	Potassium Dissolved (Pci/l as K40)	Specific Conductance Lab (µmhos)
Centereach										
SW	5.0	2.0	26.0	83.0	130	4,300	2,100	9,300	—	60
GW	6.0	2.0	4.5	1.5	2	3	3	3	—	106
PR	2.0	4.5	3.5	3.0	13	—	—	—	—	8.5
Huntington										
SW	8.0	11.0	8.0	24.5	33.0	24,000	9,300	60,500	0.4	286
GW	7.5	9.0	3.0	2.0	6.0	3	3	3	2.3	247
PR	5.5	9.5	10.0	9.0	36.0	—	—	—	0.2	28
Laurel Hollow										
SW	10.0	13.0	4.0	15.0	19.0	4,300	930	2,400	1.2	56
GW	9.5	13.0	0.0	1.0	6.0	3	2	2	0.5	57
PR	3.0	5.0	6.5	2.0	8.0	—	—	—	0.1	10
Plainview										
SW	15.0	16.0	35.0	250.0	275	24,000	640	24,000	1.75	106
GW	7.0	7.0	3.5	1.0	4.0	3	3	3	1.2	243
PR	6.0	8.5	11.0	9.0	16.0	—	—	—	0.2	22
Syosset										
SW	11.0	12.0	12.5	18.0	30.0	24,000	2,400	24,000	1.3	54
GW	15.0	13.0	6.0	41.0	47.0	13	3	3	1.4	64
PR	3.0	5.5	6.5	6.0	16	—	—	—	0.2	27

— data unavailable

No data available on
Total Coliform
Fecal Coliform
Fecal Streptococcus

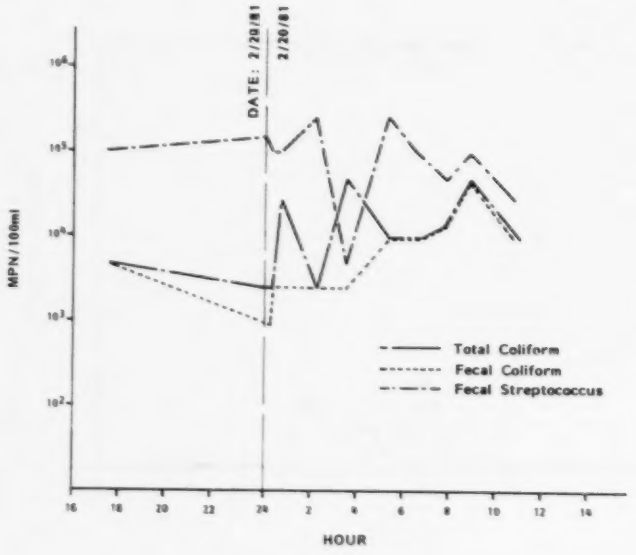


Pollutograph

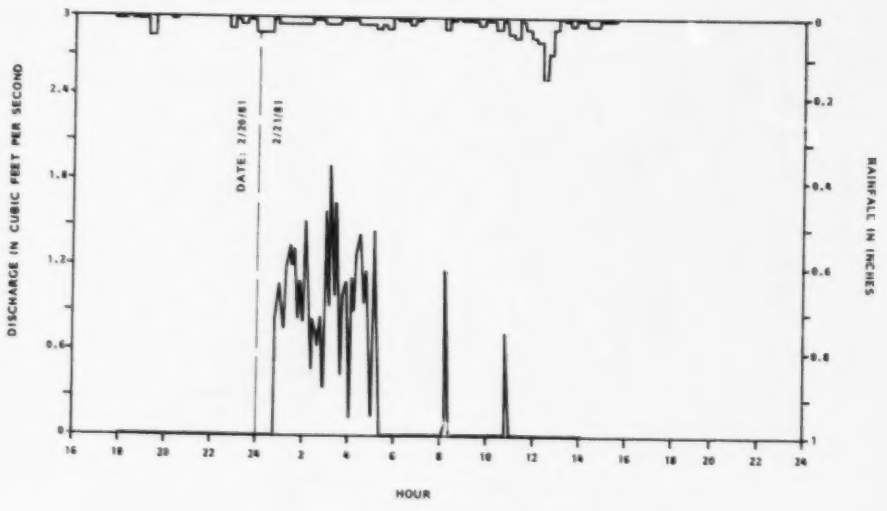


Hydrograph/Hyetograph

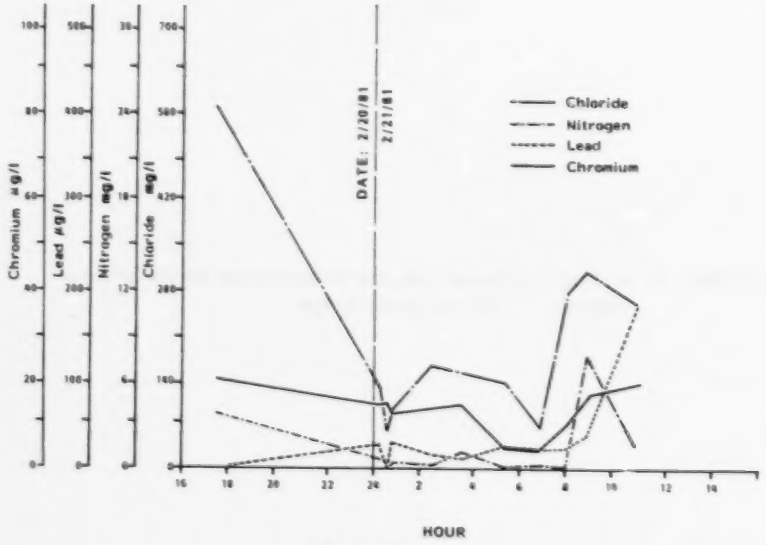
FIGURE 2-6 *Hydrograph/hyetograph, and pollutographs for the storm of June 5, 1982 at Centereach*



Pollutograph

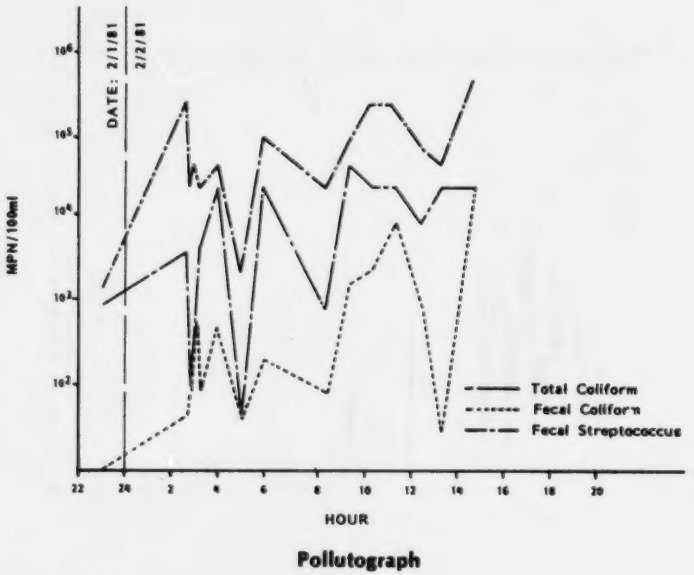


Hydrograph/Hyetograph

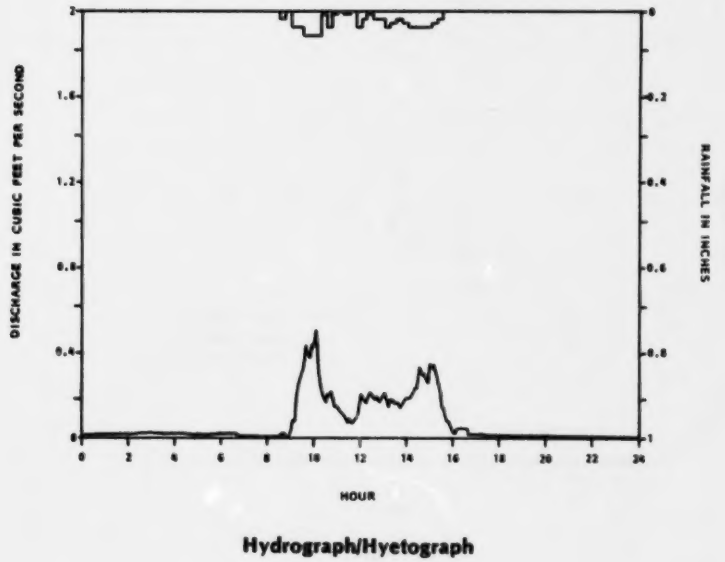


Pollutograph

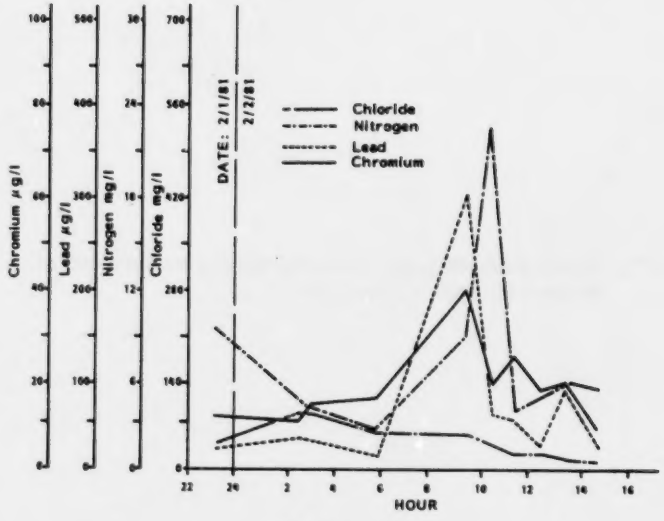
FIGURE 2-7 *Hydrograph/hyetograph, and pollutographs for the storm of February 20, 1981 at Huntington*



Pollutograph

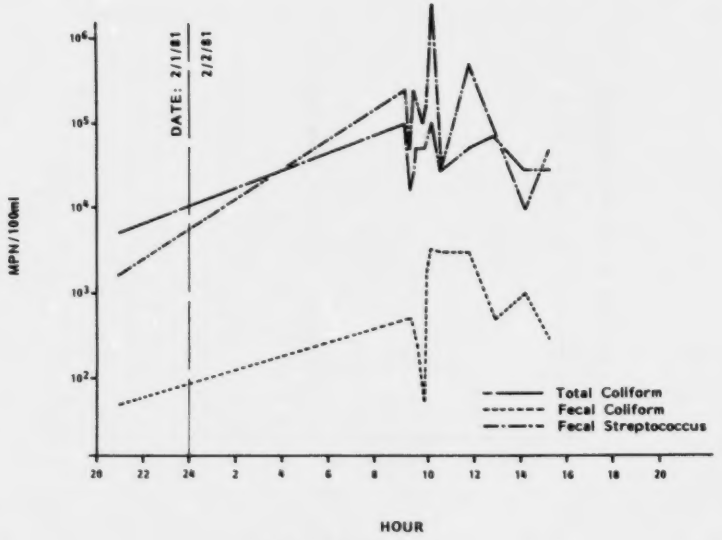


Hydrograph/Hyetograph

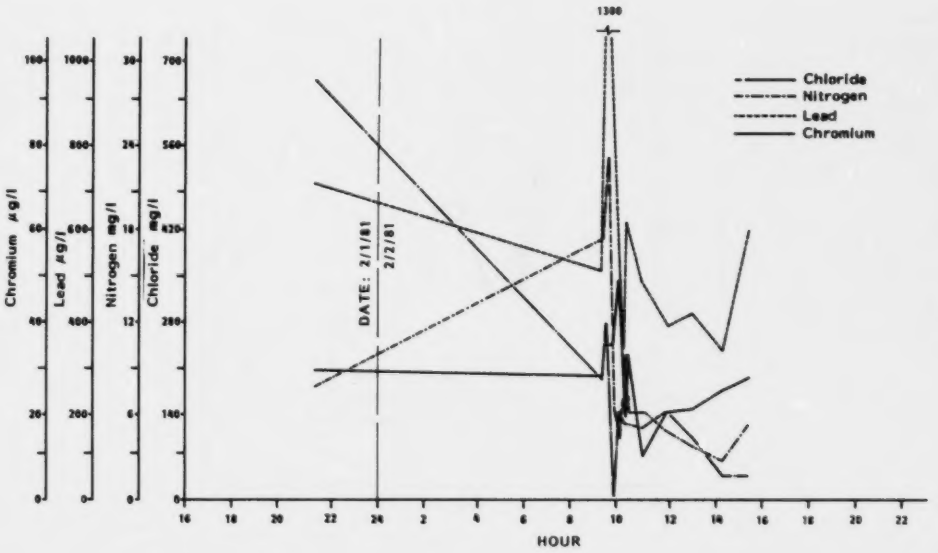


Pollutograph

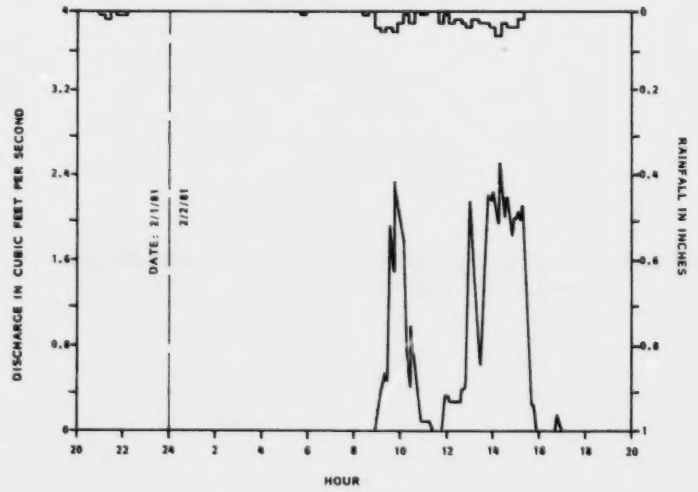
FIGURE 2-8 *Hydrograph/hyetograph, and pollutographs for the storm of February 1, 1981 at Laurel Hollow*



Pollutograph

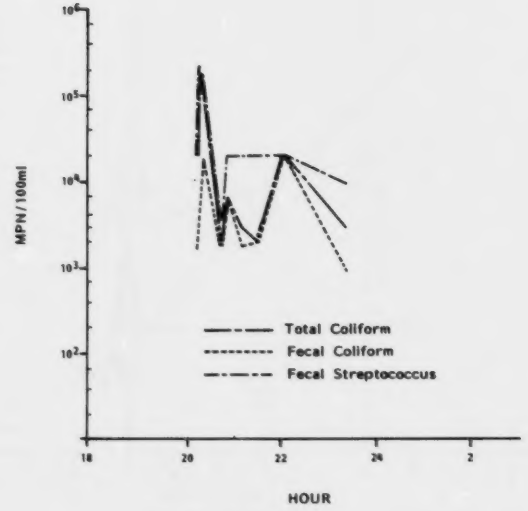


Pollutograph

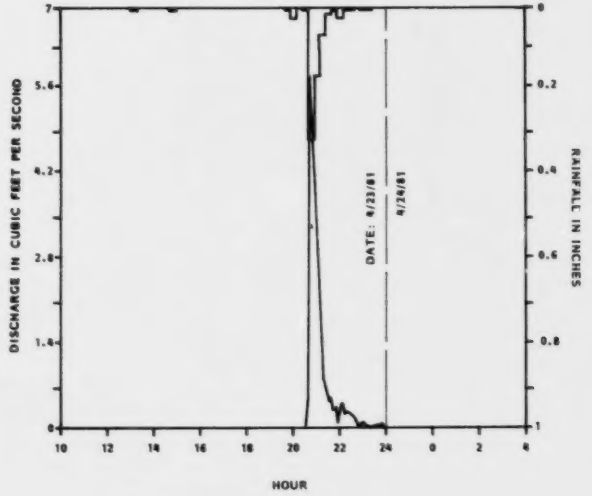


Hydrograph/Hyetograph

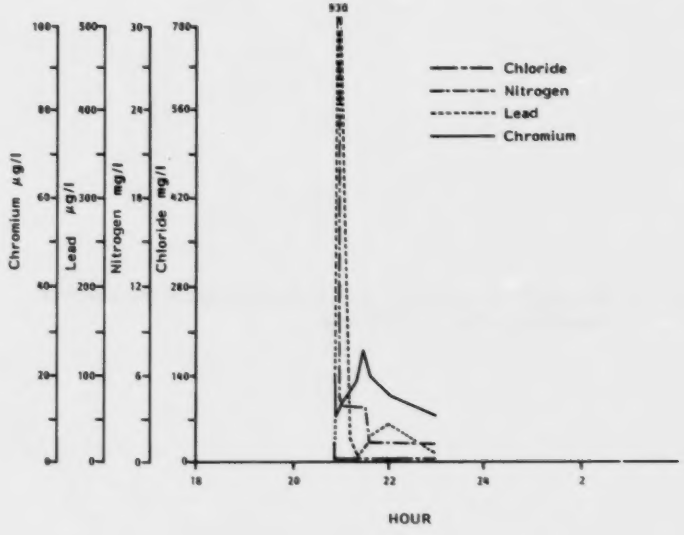
FIGURE 2-9 *Hydrograph/hyetograph, and pollutographs for the storm of February 1, 1981 at Plainview*



Pollutograph



Hydrograph/Hyetograph



Pollutograph

FIGURE 2-10 *Hydrograph/hyetograph, and pollutographs for the storm of April 23, 1981 at Syosset*

Table 2-12

PRIORITY POLLUTANTS: ACID AND BASE/NEUTRAL COMPOUNDS DETECTED, IN μG/L

	BASIN													
	Centereach		Huntington			Laurel Hollow			Plainview				Syosset	
	DATE/SOURCE													
Constituent	4/26/82 SW	4/27/82 GW	3/30/81 SW	5/7/81 GW	9/28/81 GW	3/30/81 SW	5/7/81 GW	9/28/81 GW	2/11/81 SW	5/7/81 GW	9/28/81 GW	4/14/81 SW	5/7/81 GW	9/28/81 GW
2,4,6-trichlorophenol											7			
p-chloro-m-cresol											79	2 1R		
2-chloro-phenol											16			
2,4-dichloro-phenol											12			
2,4-dimethyl-phenol	1										96			
2-nitro-phenol											11			
4-nitro-phenol					58 174R						35	4 4R		
2,4-dinitro-phenol					5 20R						12			
pentachloro-phenol	1				5 7R									
phenol	1	1 1R							1 4R			3		
bis (2 ethyl hexyl) phthalate	18	1 6R	5 9R	3,6R 47D	10	9	13				26			
2,6-dinitro toluene					4D				3 15R	5		1,1R 6D	5 4D	5
di-n-butyl phthalate	1	2 1R	11D		3R 4D								3 3D	3
diethyl phthalate	2	4 2R	4D		1R 1D							1 1R		2
chrysene					1R									
anthracene					2R									1
phenanthrene					2R									1
naphthalene			1R									1		
di-n-octyl-phthalate					8D									

R, replicate sample; D, deionized water blank; SW, stormwater; GW, ground water.

Due to the high concentrations of organic constituents found in some quality control samples, data must be interpreted with extreme caution.

Table 2-13

PRIORITY POLLUTANTS: VOLATILE COMPOUNDS, PHENOLS, AND CYANIDE DETECTED, IN μG/L

	BASIN													
	Centereach		Huntington			Laurel Hollow			Plainview				Syosset	
	DATE/SOURCE													
Constituent	4/26/82 SW	4/27/82 GW	3/30/81 SW	5/7/81 GW	9/28/81 GW	3/30/81 SW	5/7/81 GW	9/28/81 GW	2/11/81 SW	5/7/81 GW	9/28/81 GW	4/14/81 SW	5/7/81 GW	9/28/81 GW
benzene	1	1 1R	4,2MB 2B	3	2 1B		2	2	2 3R	1,1R 5B	2	1,2B 1R	2	2
1,1,1-tri-chloroethane	2	2 2R	3	23	36 24B	3	3	2		2 2R	2	1 1R	5	6
1,1-dichloro-ethane			2	5										
chloroform			2	2	3 2B		1	2			2			3
methylene chloride	10	9 13R	9,10MB 13B	20	7 20B	10	19	6	230,300R 26B,17RA	21,24R 40B	6	8,35B 8R	19	6
toluene	3	2 3R	5,3B 4MB	5	3 3B	2	3	3	4 3R	3,3R 8B	3	3,3B 2R	3	4
1,1,2,2-tetra-chloroethane			2	3	9	3							1	
1,1-dichloro-ethylene					10									
carbon tetra-chloride			1											
trichloro-fluoromethane			1	1			1							
trichloro-ethylene		41R	1	1						1 1R				
1,1,2-tri-chloroethane				1										
ethyl benzene	1	1R		1						2B				
tetrachloro-ethylene		<1		1										
aldrin	.059													
endrin aldehyde	.084													
γ-BHC		.005												
phenols	42	<2	5 <5R	<100	<100 1,000D	10 5R	<100	<100	<5	<100 <100R	<100	6 <5R	<100	<100
cyanide	5	<5	10 20R	<100	<100	20 10R	<100	<100	<10	<100 <100R	<100	<10 <10R	<100	<100

R, replicate sample; MB, method blank; B, blank; RA, room air; SW, stormwater; GW, ground water

Due to the high concentrations of organic constituents found in some quality control samples, data must be interpreted with extreme caution.

Analysis results for phenols and cyanide are of doubtful accuracy due to the possibility of sample contamination.

New York State Department of Health guidelines for organic chemicals in drinking water recommend no more than 50 μg/l for an individual organic constituent, 100 μg/l for total organic constituents, and 5 μg/l for the known carcinogens vinyl chloride and benzene. In this sampling program, there were only four instances in which these guidelines were exceeded. They are listed in table 2-14.

The following are the most commonly occurring compounds (those occurring in at least 50 percent of the samples collected):

benzene	methylene chloride
bis (2 ethyl hexyl) phthalate	toluene
chloroform	1,1,1-trichloroethane

Of these, only methylene chloride is consistently found in concentrations greater than 8 μg/l.

Table 2-14
PRIORITY POLLUTANTS DETECTED IN EXCESS OF NEW YORK STATE GUIDELINES

Basin	Date	Source	Constituent	Concentration (μg/L)
Plainview	9-28-81	groundwater	p-chloro-m-cresol	79
Plainview	9-28-81	groundwater	2,4-dimethylphenol	96
Huntington	9-28-81	groundwater	4-nitrophenol	58
Plainview	2-11-81	stormwater	methylene chloride	230

2.5.2.3 Bacteria in stormwater and groundwater. Total coliforms, fecal coliforms, and fecal streptococci are known as "indicator" organisms because they indicate the presence of sewage and, ideally, are correlated with the number of pathogens in a water sample. Although the use of coliforms as an indicator has been criticized, EPA's safe drinking water standards are written in terms of coliforms rather than pathogens, as are standards for recreational waters and shellfishing areas (Mallard, 1980).

Most coliform bacteria in runoff are native soil organisms that are washed off soil particles by water running over the land surface. Fecal coliforms and fecal streptococci, however, are contributed by warm-blooded animals. In urban areas, these bacteria are most likely due to fecal material from dogs, cats, rodents, and other small animals. On Long Island, ducks and seagulls are also significant contributors of bacteria to surface water.

Counts of total coliforms, fecal coliforms, and fecal streptococci in stormwater, compiled by Mallard (1980) from several references, range as follows:

total coliforms	10^3 to 10^5 per 100 ml.
fecal coliforms	10^2 to 10^4 per 100 ml.
fecal streptococci	10^2 to 10^5 per 100 ml.

Counts from the 306 stormwater samples analyzed for bacteria during this study generally fall within these ranges, although values that fall an order of magnitude above or below these range limits are not uncommon.

Table 2-15 shows the minimum, maximum, and median values of the three indicator bacteria at each of the five sites studied.

Table 2-15
MINIMUM, MAXIMUM, AND MEDIAN NUMBER OF BACTERIA (MPN) IN STORMWATER FOR ALL SAMPLES, IN MPN PER 100 ML

Bacteria	Minimum	Maximum	Median
	Centereach		
Total coliforms	240	43,000	4,300
Fecal coliforms	4	43,000	930
Fecal streptococci	640	46,000	24,000
	Huntington		
Total coliforms	2,400	1,100,000	24,000
Fecal coliforms	6	240,000	9,300
Fecal streptococci	2,400	1,100,000	126,650
	Laurel Hollow		
Total coliforms	240	43,000	4,300
Fecal coliforms	4	43,000	930
Fecal streptococci	640	460,000	24,000
	Plainview		
Total coliforms	240	1,100,000	24,000
Fecal coliforms	43	43,000	640
Fecal streptococci	150	2,400,000	24,000
	Syosset		
Total coliforms	240	1,100,000	24,000
Fecal coliforms	9	240,000	2,400
Fecal streptococci	430	1,100,000	24,000

Table 2-16 shows the median and range of the three indicator bacteria for all sampled storms in units of number of bacteria per acre per inch of precipitation. Low density residential (Laurel Hollow) and nonresidential (Huntington, Plainview) areas appear to contribute the least amount of bacteria to stormwater, while medium density residential (Syosset) and strip commercial (Centereach) areas contribute the most.

As has been stated previously in this report, there was a problem in obtaining accurate flow data from the Huntington site due to the fact that the electromagnetic flow sensor in the inflow pipe was often submerged, and during a storm there was sometimes reverse flow in the pipe. Therefore, although the concentration of bacteria at Huntington as shown in Table 2-15 was relatively high, the load of bacteria as shown in Table 2-16 was relatively low. It is fair to assume that the discharge volume used in computing bacteria loads at Huntington was low, and that bacteria loads at that site are probably higher than those shown in Table 2-16.

Table 2-16
MINIMUM, MAXIMUM, AND MEDIAN NUMBER OF BACTERIA (MPN) PER STORM FOR ALL SAMPLED STORMS, PER ACRE PER INCH OF PRECIPITATION

A. Total Coliforms

Basin	Minimum	Maximum	Median
Centereach	1.1×10^{8}	2.23×10^{11}	1.2×10^{10}
Huntington	1.02×10^{8}	7.08×10^{10}	2.75×10^{9}
Laurel Hollow	1.4×10^{7}	7.02×10^{9}	5.1×10^{8}
Plainview	1.3×10^{7}	5.32×10^{10}	1.74×10^{9}
Syosset	8.43×10^{8}	2.14×10^{11}	3.04×10^{10}

B. Fecal Coliforms

Basin	Minimum	Maximum	Median
Centereach	8.2×10^{8}	7.54×10^{10}	1.5×10^{9}
Huntington	1.5×10^{8}	1.23×10^{10}	5.64×10^{8}
Laurel Hollow	1.6×10^{8}	4.3×10^{8}	1.0×10^{8}
Plainview	3.4×10^{8}	5.2×10^{8}	7.39×10^{8}
Syosset	4.22×10^{8}	4.37×10^{10}	7.51×10^{9}

C. Fecal Streptococci

Basin	Minimum	Maximum	Median
Centereach	3.4×10^{8}	9.44×10^{10}	3.66×10^{40}
Huntington	4.85×10^{7}	9.45×10^{10}	9.68×10^{9}
Laurel Hollow	2.36×10^{8}	8.9×10^{10}	3.0×10^{8}
Plainview	1.3×10^{8}	1.3×10^{11}	1.2×10^{10}
Syosset	8.01×10^{8}	3.2×10^{11}	4.63×10^{10}

Table 2-17 shows the median and range of the three indicator bacteria for all five sites by season. Although the total coliforms show no significant difference between the warm and cool season, fecal coliforms and fecal streptococci in stormwater increase by one to two orders of magnitude during the warm season. This analysis is in agreement with the seasonal variations in indicator bacteria reported by Mallard (1980, p. 6).

Geldreich and Kenner (1969) found that the ratio of fecal coliforms to fecal streptococci (FC:FS) in human feces and in water polluted with human waste is always greater than 4.0, whereas the FC:FS ratio in feces from farm animals, cats, dogs, and rodents, and in separate stormwater systems and farmland drainage, is less than 0.7.

Although the FC:FS ratio gives some indication of the source of the bacteria, Mallard (1980) warns that factors such as temperature, pH, metal concentration, nutrient availability, and other environmental variables will alter the ratio once the organisms enter the receiving water. These effects can be minimized by collecting water samples as soon as possible, near the source of the contamination, before the receiving water body is reached.

Additionally, the FC:FS ratio for samples that contain water from a mixture of nonpoint sources must be interpreted with caution. For example, if most of the contamination in a sample comes from nonhuman sources, a small amount of human sewage might not cause a sufficient upward shift in the overall ratio to indicate the possible presence of human pathogens.

Table 2-17
SEASONAL COMPARISON OF MINIMUM, MAXIMUM, AND MEDIAN NUMBER OF BACTERIA (MPN) PER STORM FOR ALL SAMPLED STORMS, PER ACRE PER INCH OF PRECIPITATION

A. Cool Season (October through March)

Bacteria	Minimum	Maximum	Median
Total coliforms	1.3×10^{7}	7.4×10^{11}	1.9×10^{9}
Fecal coliforms	1.6×10^{8}	5.2×10^{9}	6.1×10^{8}
Fecal streptococci	1.3×10^{8}	1.2×10^{11}	8.01×10^{8}

B. Warm Season (April through September)

Bacteria	Minimum	Maximum	Median
Total coliforms	7.1×10^{7}	2.23×10^{11}	2.3×10^{9}
Fecal coliforms	1.5×10^{8}	7.54×10^{10}	1.23×10^{10}
Fecal streptococci	4.85×10^{7}	3.2×10^{11}	4.16×10^{10}

Table 2-18 shows the minimum, maximum, and median FC:FS ratios for stormwater runoff samples collected at each of the five sites studied, along with the number of samples from which these statistics were determined. In each case, the median ratio is well below 0.7, indicating that the probable source of the bacteria is animal waste. Two of the maximum values, 5.6 for Laurel Hollow and 16.0 for Huntington, are above the 4.0 limit which is thought to be generally indicative of contamination from human sources. FC:FS ratios of this magnitude, however, were extremely rare, occurring in only 7 of the 279 samples collected (2.5 percent). Ratios in excess of 4.0 were found in only 1 of 58 samples collected at Laurel Hollow (1.7 percent), and in only 6 of 77 samples collected at Huntington (7.8 percent).

Soil has generally been found to be effective in removing bacteria from water (Mallard, 1980). Movement of bacteria into groundwater is limited by the straining of bacteria at the soil surface and by adsorption to clay particles, so that deterioration of groundwater quality by bacteria is not likely to be a problem. Studies on Long Island have shown that a horizontal travel distance of 20 feet through a saturated soil medium is sufficient to remove all significant bacteria loads from contaminated water (Ehrlich and others, 1979).

Table 2-18
FECAL COLIFORM TO FECAL STREPTOCOCCI RATIO[a]

Site	Minimum	Maximum	Median	Number of Samples
Centereach	0	1.8	.10	27
Huntington	0	16.0	.20	77
Laurel Hollow	0	5.6	.05	58
Plainview	0	1.8	.03	60
Syosset	0	1.0	.10	57
TOTAL				279

[a]FC:FS > 4.0 generally indicative of human waste as bacteria source: FC:FS < 0.7 generally indicative of animal waste as bacteria source (Geldreich and Kenner, 1969).

Figure 2-11 is a map of Long Island with contours indicating approximate depth to groundwater in 1978. (Water levels during 1978 were close to the long-term average.) The map can be used as a general indication of where depth to water is sufficient for the excavation of recharge basins, but it is not meant to replace detailed site evaluation. At all five of the sites sampled during this study, the recharge basins were found to be effective in removing bacteria from stormwater before it reached the water table. The Laurel Hollow basin, with the shallowest depth to groundwater (22 feet), was as effective in removing bacteria as the basins where the thickness of the unsaturated zone was considerably greater. Values of total coliforms, fecal coliforms, and fecal streptococci in groundwater beneath all the recharge basins, sampled one to two days after a storm event, were almost invariably less than 3.0 MPN/100 ml.

Loads of selected constituents in stormwater inflow and in water that infiltrates through the recharge basin floor and reaches the groundwater table are shown in Table 2-19 (A-E). This table lists the load, in pounds, for each sampled storm.

The stormwater constituents selected for this analysis are chromium and lead, which are heavy metals associated with gasoline and industry, and chloride and nitrogen, which are associated with fertilizers and animal waste. In addition, chloride is derived from the salt used for the deicing of roads during the winter months.

Loads of chromium and lead in stormwater are generally low, ranging from virtually none (0.001, 0.003 lbs., respectively) to tenths of a pound. In instances where there is a large influx of lead into the basin, as at Plainview, there is a large degree of removal. For example, for the storm on February 11, 1982 at Plainview, the lead load in the stormwater was 2.03 pounds, but the same water when it reached the water table contained only 0.01 pounds of lead. The same is true of chromium although the largest influx of chromium into a basin was only 0.152 lbs. (June 16, 1982 at Centereach).

A comparison between chloride and nitrogen loads in stormwater and those in groundwater shows little or no removal of these constituents as the stormwater moves through the unsaturated zone beneath the recharge basin. In fact, in many instances, the load in the groundwater appears to be greater. This is because much of the load of these constituents in groundwater is derived from sources other than stormwater, such as septic tank and cesspool effluent and fertilizers.

Note that the chloride input to the recharge basins is often extremely high during the winter months (118 lbs. at Centereach on March 4, 1982; 163 lbs. at Huntington on February 19 and 20, 1981; 1,558 lbs. at Huntington on January 23, 1982). Note also that the low density residential area at Laurel Hollow exhibits relatively small load values for all constituents.

2.5.2.4. Basin Soil

a) *Physical Characteristics*

Most of the soils of Long Island are classified as either loamy soils or sandy soils (Aronson & Seaburn, 1974). Loamy soils contain a mixture of clay, silt and sand in approximately equal proportions. Sandy soils contain mostly sand and only small percentages of clay and silt. Aronson & Seaburn, (1974), found that differences in soils in the drainage area of a recharge basin probably have little effect on basin efficiency.

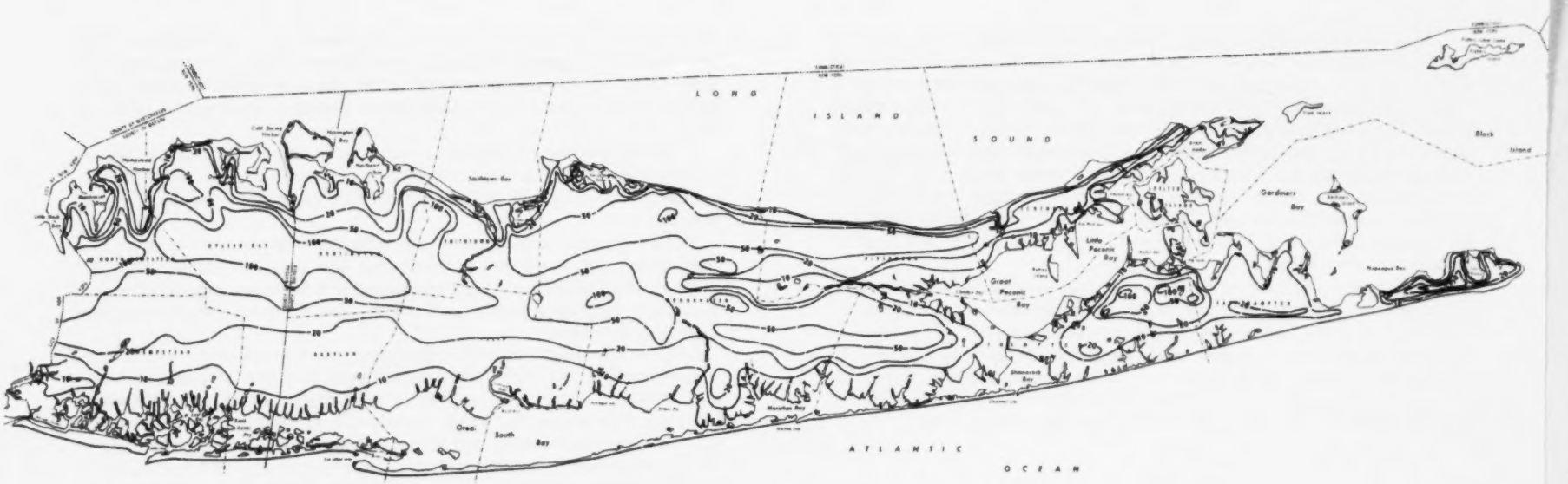


FIGURE 2-11 *Approximate depth to groundwater on Long Island, in feet*

When recharge basins are constructed, all natural soil and vegetal cover are stripped away. A new soil layer develops with time, because of the gradual accumulation of fine-grained sediment and plant material eroded from the drainage area, and because of the natural soil-forming processes within the basin. Although new vegetation takes hold very quickly, it remains sparse for several years following construction.

Recharge basin efficiency can be hindered by low infiltration rates that result from:

i. a high percentage of silt, clay and organic debris that washes in from the drainage area and fill the interstices of the natural deposits, and

ii. a lack of plant growth on the floor of the basin.

Plant growth on the basin floor enhances infiltration because the plant root system keeps the soil layer loose and permeable, and provides channels for infiltrating water.

During this study, it was observed that the soil in the newly constructed, sparsely vegetated Laurel Hollow basin tended to cake and to clog with silt, temporarily affecting recharge efficiency. This was probably a result of the sediment load associated with construction in the drainage area, as well as the lack of vegetation in the basin. The Syosset basin also drains a residential area, but here the basin bottom never became plugged or clogged during the course of this study because the vegetation was well established and the bottom soil is thoroughly broken up by root systems.

b) *Basin Soil Analyses*

Basin-bottom soil samples were collected from the sites at Huntington, Laurel Hollow, Plainview and Syosset on June 5, 1981. (No samples were collected at Centereach because this basin was added later in the study.)

The soil samples were collected at two arbitrarily chosen spots approximately five feet in front of the concrete apron at the outfall pipe. Because the basin at Huntington contains two or more feet of water at all times, the soil here was taken from two locations near the water line at the base of the service ramp. In each case, two samples of the top few inches of soil were collected. One was placed in a pretreated liter glass jar with a teflon seal for herbicide and insecticide analysis, and the other in a liter plastic container for metals analysis.

Chromium concentrations in basin soil range from 10 μg/g (micrograms per gram of soil) to 20 μg/g. The lead concentrations range from a low of 70 μg/g at Laurel Hollow to a high of 1200 μg/g at Plainview. The other metals found in significant concentrations, i.e. iron, maganese, and zinc, are native to the soil (Ku and others, 1978).

The concentration of chromium in basin-bottom soil appears to be uniformly low and independent of land use (20 μg/g at Huntington, 10 μg/g at Laurel Hollow, Plainview and Syosset). The concentration of lead, however, is highest (1200 μg/g) at Plainview, where the basin receives storm runoff from a highway, and lowest (70 μg/g) at Laurel Hollow, where the basin is newly con-

Table 2-19
LOAD, IN POUNDS, OF SELECTED CONSTITUENTS IN STORMWATER AND LOAD REACHING THE WATER TABLE AT THE RECHARGE BASINS

Date	Chromium, Total		Lead, Total		Chloride, Dissolved		Nitrogen, Total	
	Storm-Water	Ground-Water	Storm-Water	Ground-Water	Storm-Water	Ground-Water	Storm-Water	Ground-Water
A. CENTEREACH								
3-4-82	.015	.027	0.740	.710	118.0	12.8	5.40	1.30
3-16-17 -82	.012	—	0.107	—	2.05	—	0.549*	—
4-26-82	.009*	.012	0.340*	.010	18.5*	16.1	1.23	0.873
6-1-2 -82	.010	.004*	0.089	.007	2.05	35.7	0.586*	1.41*
6-5-82	.025*	.024	1.05	.024	17.1	85.8	6.30*	3.69*
6-16-82	.152*	.002	0.173*	.007	2.54*	15.5	1.40*	0.251
B. HUNTINGTON								
9-18-80	.004	.001	.024	.001	0.958	4.37	.474	1.77
10-25-80	—	—	—	—	—	—	—	—
2-19-20 -81	.014	.006	.024	.006	163.0	5.30	.720	0.650
2-23-24 -81	.003	.002	.028	.003	51.6	16.3	.192	2.60
3-30-81	.004	.005	.003	.005	13.1	11.5	.050	3.75
4-14-81	.001	0.003	.003	0.0	29.2	5.47	0.483	1.64
4-23-81	.001	0.0	.001	0.0	0.949	0.811	0.056	0.422
5-11-81	.010	0.005	.129	0.001	21.8	15.8	1.03	4.78
5-29-81	—	—	—	—	—	—	2.22	—
7-20-81	.021	0.029	.103	0.042	3.73	26.9	1.80	4.30
9-15-81	.066*	0.049	.099*	0.042	9.06	238.0	29.2	43.6
1-23-82	.120	—	.931	—	1560.0	—	52.7*	—
C. LAUREL HOLLOW								
11-18-80	0.0	0.0	0.002	0.002	0.309	0.668	0.207	.090
11-24-80	0.001	—	0.0	—	0.004	—	0.051	—
12-9-80	0.0	0.0	0.0	0.0	0.017	0.024	0.001	.008
2-1-2 -81	0.008	0.004	0.041	0.003	12.4	3.79	3.04	.375
2-19-20-81	0.010	0.003	0.021	0.004	2.75	1.93	2.33	.771

* estimated value
— data unavailable

Table 2-19 (Continued)
LOAD, IN POUNDS, OF SELECTED CONSTITUENTS IN STORMWATER AND LOAD REACHING THE WATER TABLE AT THE RECHARGE BASINS

Date	Chromium, Total		Lead, Total		Chloride, Dissolved		Nitrogen, Total	
	Storm-Water	Ground-Water	Storm-Water	Ground-Water	Storm-Water	Ground-Water	Storm-Water	Ground-Water
				C. LAUREL HOLLOW (Continued)				
2-23-81	0.006*	0.003	0.005	0.002	.760	.688	.187	.206
3-30-81	0.0	0.0	0.004	0	.883	.350	.227	.040
5-11-81	0.0	0.0	0	0	.041	.020	.021	.016
7-3-81	0.0	—	0.015	—	.284	—	.542	—
				D. PLAINVIEW				
9-18-80	0.001	0.001	0.030	0.0	0.364	2.44	0.154*	0.126
10-25-80	0.027	0.002	0.305	.002	9.66	55.2	1.72	1.90
11-18-80	0.016	0.015	0.176	.005	6.1	60.0	0.385*	1.9
11-24-80	0.095	0.007	1.08	.010	10.8	172.0	0.696*	2.75*
12-9-80	0.0	0	0.001	0.0	0.064	0.388	0.008	0.006
12-30-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-1-2 -81	.044	.017	1.16	.007	13.4	7.45	.859	.199
2-11-81	.071	.016	2.03	.01	54.5	65.3	19.2	1.58
9-8-81	—	0.016	—	0.011	—	65.3	2.55	1.32
2-2-82	0.0	0.0	0.88	0.0	41.0	392	5.90*	7.60*
				E. SYOSSET				
10/25/80	.008	.012	.013	0.0	2.63	15.3	0.895	18.4
4/14/81	.005	.005	.012	.001	3.72	6.51	1.14	1.86
4/23/81	.010	.008	.175	.015	3.73	7.34	5.77	1.54
5/29/81	.007*	—	.068*	—	2.30*	—	3.19	—
7/20/81	.030	—	.075	.090	1.89	3.10	2.66	1.03
7/29/81	.001	—	.004	—	0.179	—	.226	—
9/15/81	.017	.014	.037	.103	2.67	2.56	2.16	1.93
12/1/81	.028	.002	.056	.803	6.37	13.1	0.593	5.49
12/15-16/81	.003	.017	.028	.081	3.12	10.9	0.323*	1.89*

* estimated value
— data unavailable

structed and drains a low-density residential area. This supports the assumption that the removal of metals, especially those in particulate form, from stormwater as it moves from soil surface to the water table is caused largely by their adsorption onto near-surface soil particles.

The basin bottom soil samples were also analyzed for pesticides (herbbicides and insecticides). These substances are used by local residents, professional exterminators, and government agencies, especially during the spring and early summer. They are generally insoluble in water, but are moderately to freely soluble in organic solvents. They can also enter recharge basins mixed with water or sorbed on sediment particles, or as dry fallout.

Persistence of these compounds in soil and water, i.e. the time required for total decomposition, ranges from days to many years. Breakdown and mechanical dispersion rates depend on such factors as temperature, light, humidity, air movement, volatility of the compounds, and especially microbiologic activity (Seaburn & Aronson, 1974).

The majority of pesticide constituents analyzed for were either not present or were below detectable limits. The exceptions are chlordane, DDD, DDE, DDT, diazinon, dieldrin, and gross PCB; they were found in concentrations ranging from 0.6 μg/kg (dieldrin at Huntington) to 2700 μg/kg (chlordane at Syosset).

These results are supported by a similar study by Seaburn and Aronson (1974), who found low concentrations (up to 0.08 μ/l) of DDD, DDT and silvex in sampled stormwater, but much higher concentrations in basin soil. For example, the DDT content of soil from each of the three basins they sampled ranged from 18,000 to 300,000 times the concentration in stormwater inflow.

There are three reasons, alone or in combination, for the presence of pesticides in basin soil in concentrations several orders of magnitude higher than those in inflow samples. These are 1) extremely small amounts of pesticides enter a basin during any one storm and are concentrated over time in the soil layer; 2) pesticide use has been curtailed in recent years, and pesticides found in basin soil result mainly from use (and overuse) in the past; and 3) most pesticides are washed from the drainage area into the recharge basin during the storm(s) immediately following their application.

2.6 REFERENCES CITED

Aronson, D.A., and Seaburn, G.E., 1974, *Appraisal of Operating Efficiency of Recharge Basins on Long Island, New York, in 1969*: U.S. Geological Survey Water-Supply Paper 2001-D, p. D1-D22.

Ehrlich, Garry G., Ku, Henry F.H., Vecchioli, John, and Ehlke, Theodore A., 1979, *Microbiological effects of recharging the Magothy aquifier, Bay Park, New York, with tertiary-treated sewage:* U.S. Geological Survey Professional Paper, 751-E, 18 p.

Geldreich, E.E., and Kenner, B.A., 1969, "Concepts of fecal streptococci in stream pollution:" *Journal Water Pollution Control Federation,* v. 41, p. R336-R352.

Koppelman, L.E., 1978, *208 Areawide Waste Treatment Management,* Part C. Inventories and projections, 102 p.

Ku, H.F.H., and Katz, B.G., Sulam, D.J. and Krulikas, R.K., 1978, Scavenging of Chormium and Cadmium by aquifer material ——South, Farmingdale-Massapequa area, Long Island, New York: in *Ground Water,* v. 16, no. 2, p. 112-118, 3 figs.

Lounsbury, Clarence, Howe, F.B., Zautner, R.E., Moran, W.J., and Beers, P.D., 1928: *Soil survey of Suffolk and Nassau Counties, New York:* U.S. Department of Agriculture, Bureau of Chemistry and Soils, ser. 1928, no. 28, 46 p.

Mallard, G.E., 1980, *Microorganisms in stormwater—A summary of recent investigations:* U.S. Geological Survey Open-File Report 80-1198, 18 p.

Seaburn, G.E., 1969, *Effects of urban development on direct runoff to East Meadow Brook, Nassau County, Long Island, New York:* in U.S. Geological Survey Professional Paper 627-B, p. B1-B14.

Seaburn, G.E., and Aronson, D.A., 1973, "Catalog of recharge basins on Long Island, New York, in 1969:" *New York State Department of Environmental Conservation Bulletin 70,* 80 p.

Seaburn, G.E., and Aronson, D.A., 1974, *Influence of recharge basins on the hydrology of Nassau and Suffolk Counties, Long Island, New York:* U.S. Geological Survey Water-Supply Paper 2031, 66 p., 30 figs., 1 pl.

Versar, Inc., 1980, *Monitoring of Toxic Pollutants in Urban Runoff:* A guidance manual—Interim final report, 85 p.

Versar, Inc., 1982, Nationwide Urban Runoff Program (NURP): *Special Metals Project—Report of Analytical Data (Five Samples) for the Long Island,* New York NURP Study Area.

Weston, 1977, Wet-weather, non-point source pollutant loads in Nassau and Suffolk Counties (draft).

Section 3 - The Surface Water Component; Detailed Study Areas in Nassau and Western Suffolk

3.0 INTRODUCTION

As indicated in Section 1, the *Long Island Comprehensive Waste Treatment Management Plan* implicated stormwater runoff as the major source of bacterial loading to the coastal waters. The elevated coliform counts associated with urban runoff have led to a ban on the harvesting of shellfish in approximately one-fourth of the most productive portions of all Long Island bays. The loss of an important beneficial use of the uncertified or conditionally certified areas, depicted in Figure 3-1, led to the investigation of three distinct types of control measure, each intended to reduce the number of coliform bacteria reaching marine waters during and immediately following storm events.

The following pages present a discussion of the test sites or study sites shown in Figure 3-2, the control measures evaluated, sampling procedures, control measure or load reduction analyses, and the development and use of the *Matrix Manipulation Model* (MMM) to estimate the load reductions required to open various portions of the uncertified south shore areas. Section 3.1 deals with the use of a control measure designed to minimize pollutant loads by eliminating or reducing the volume of runoff reaching estuarine waters. Section 3.2 deals with the use of an impoundment to slow the movement of runoff and thus promote both the sedimentation of materials to which coliform bacteria adhere and, to a limited extent, the die off of bacteria within the water column. Section 3.3 deals with the use of intensive street sweeping to reduce the amount of sediment, animal fecal material, and debris available for transport in runoff. The importance of removing such material was indicated by the fact that the ratio of the fecal coliform content of runoff samples to their fecal streptococci content was always so low as to preclude a human origin and strongly implicate an animal one. Section 3.4 deals with the mathematical modeling and development of plan alternatives, both of which were performed by the engineering consultant. Section 3.5 briefly discusses the investigation into the presence of Salmonella in stormwater runoff and receiving waters.

PERRY AVENUE, BAYVILLE, SITE

3.1.1. Site Description. The Perry Avenue study site comprises a drainage area of 65.6 acres located within the Incorporated Village of Bayville in northeastern Nassau County. The drainage area boundaries are determined primarily by the natural topography and secondarily by man-made alterations of the landscape; i.e. roadway and sidewalk elevations. Figure 3-3 shows a topographic map and aerial photograph of the study site.

The drainage area is bounded in the north and east by a glacial ridge composed of till. On the east this boundary excludes a newly constructed medium density residential development, from which runoff is directed to a separate recharge basin. Mill Neck Creek, a salt water estuary, constitutes the southern boundary; and an elevated concrete sidewalk adjacent to and parallel with the west side of Perry Avenue, the western boundary.

Preceding page blank

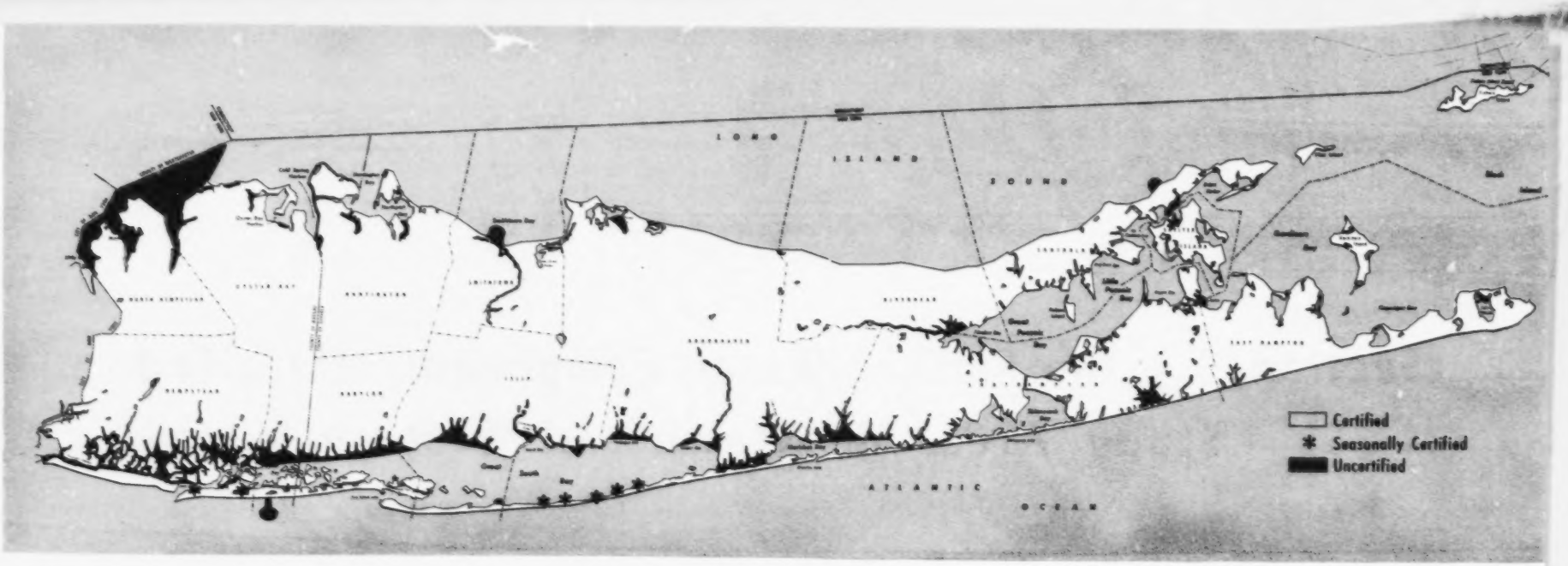


FIGURE 3-1 *Map showing uncertified or conditionally certified areas on Long Island*

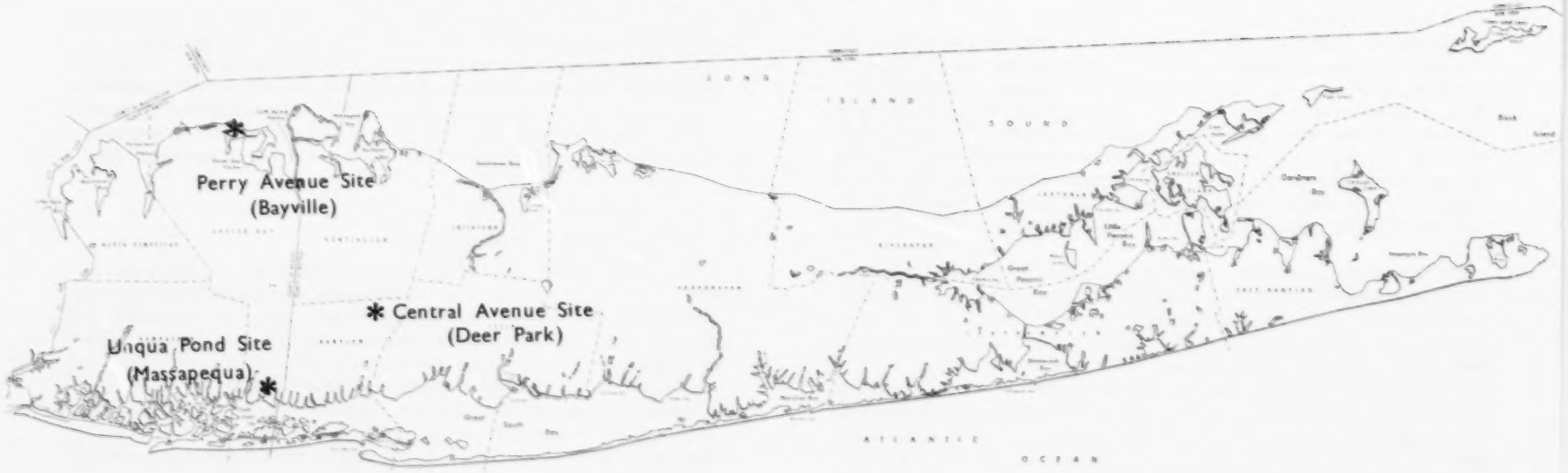
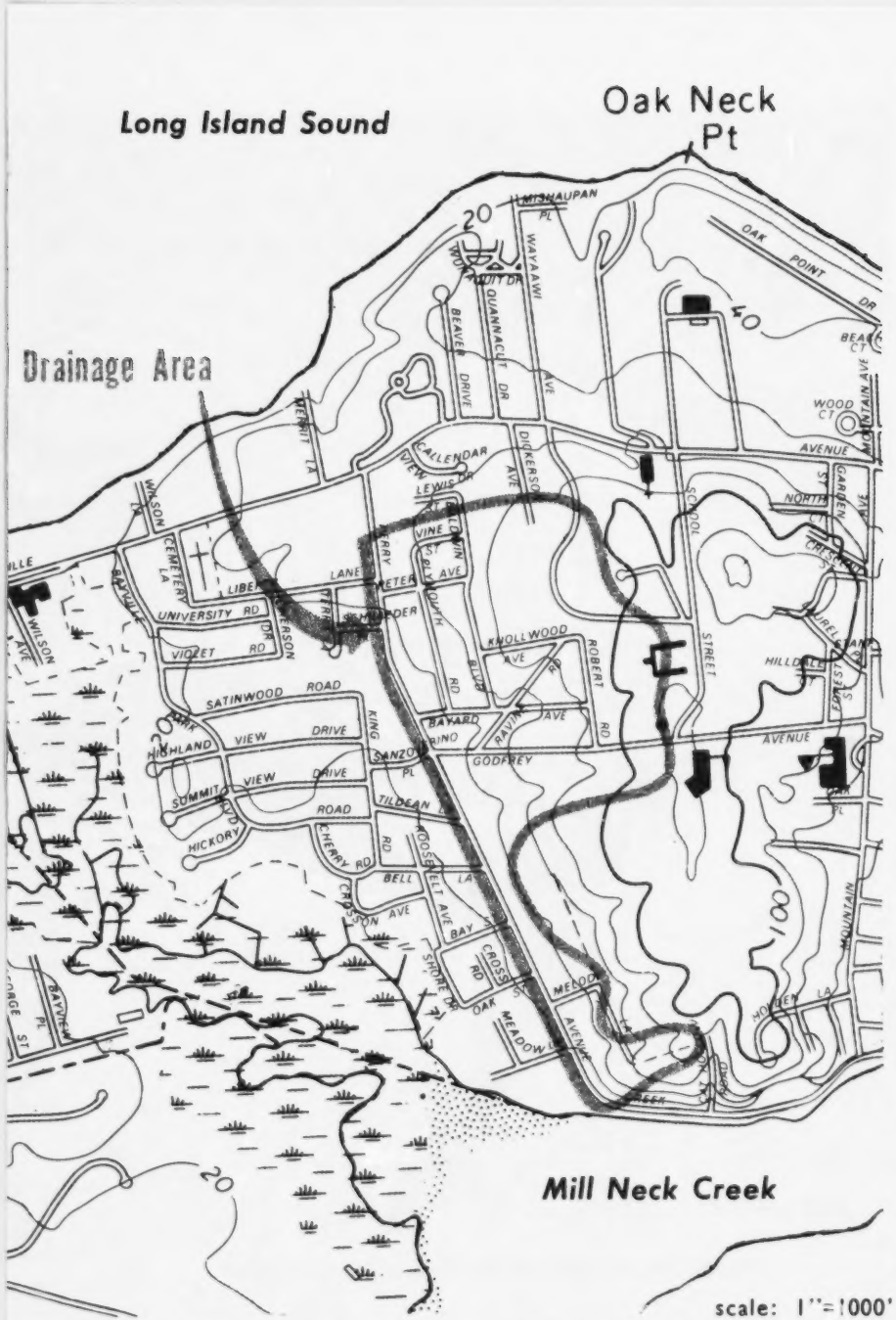


FIGURE 3-2 *Map showing study sites for surface water investigations*



Reproduced from best available copy.

FIGURE 3-3 *Topographic map and aerial photograph of Perry Avenue Site, Bayville*

The land surface within the drainage area slopes to the south. The gradient is relatively steep, 40 ft. per mile, which is typical of Long Island's north shore morainal areas.

All stormwater runoff from this drainage area, as well as from the areas to the east and west, discharges to Mill Neck Creek, which is part of Oyster Bay. Prior to 1979, when construction of the stormwater drainage system was completed, runoff had flowed overland south along Perry Avenue, finally discharging into Mill Neck Creek. At that time the portion of Mill Neck Creek south of Perry Avenue was uncertified for shellfish harvesting. Water quality data obtained in 1978 exhibited geometric mean dry weather total/fecal coliform densities of 82/27 MPN/100 ml and geometric mean wet weather total/fecal coliform densities of 298/111 MPN/100 ml.

After the construction of the stormwater system was completed, additional samples were taken. These samples, collected over 1980-1981 showed coliform densities below the allowable maxima specified in the shellfishing certification standards promulgated by NYSDEC. For two adjacent sampling points closest to the stormwater drainage system outfall wet weather average total coliform densities of 15 and 23 MPN/100 ml were determined. Only nine percent of all wet weather samples exhibited total coliform densities greater than 330 MPN/100 ml. The NYSDEC recertified a portion of Mill Neck Creek in 1981 and reopened it to shellfish harvesting. Figure 3-4 indicates the extent of the certified area. At present Mill Neck Creek still receives direct overland runoff from the drainage areas adjacent to the Perry Avenue drainage area as well as the freshwater flow from a stream-lake system draining a low density residential area.

Land use within the study site drainage area is exclusively medium density residential, consisting of single family dwellings most of them on 60 ft. × 100 ft. building plots. Fifteen percent of the drainage area, 9.8 acres, consists of paving or other impervious surfaces.

Soils of the Urban Land — Plymouth complex underlie most of the drainage area. The Plymouth complex consists of deep, excessively drained soils. In wooded areas these soils typically have a very dark, grayish brown loamy sand surface layer 4 inches thick. The subsoil layers are yellowish brown and brown loamy sand. The substratum from 27 to 43 inches is yellowish brown loose gravelly coarse sand. Permeability is high throughout the soil profile. This drainage area consists of gently sloping to rolling hillsides. (US Department of Agriculture, 1982)

3.1.2. Sampling Program. Storm event runoff sampling was accomplished by personnel of the Bureau of Water Pollution Control, Nassau County Department of Health. Field personnel were deployed prior to the occurrence of storm events, when the monitoring of weather broadcasts indicated that a significant rainfall was likely. National Oceanic and Atmospheric Administration (NOAA) weather radio broadcasts from New York City were the primary storm information sources. Secondary sources were the NOAA broadcasts from New Haven, Conn.

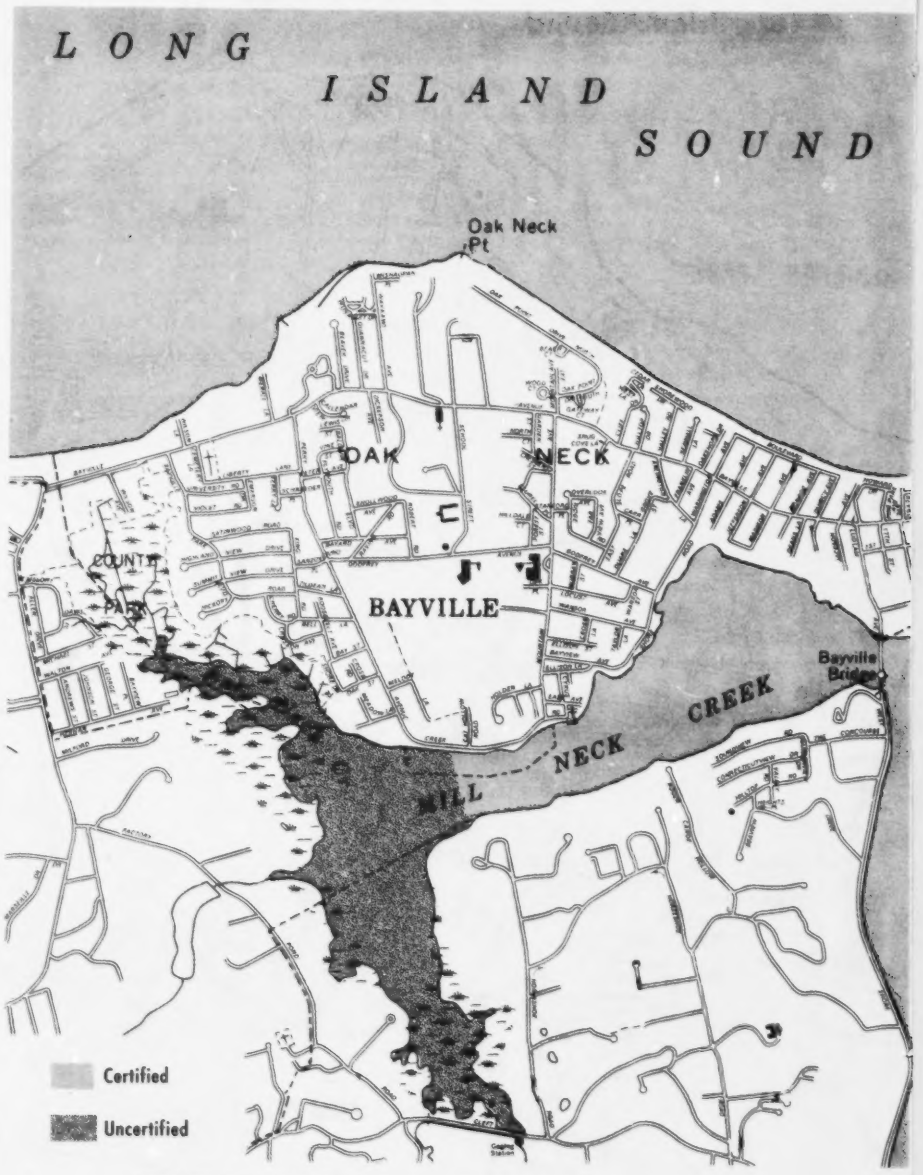


FIGURE 3-4 *Certified shellfish areas of Mill Neck Creek*

Runoff from a 1.17 acre section of the 65.6 acre drainage area was evaluated. Stormwater draining from this area was directed into a shallow solid bottom catch basin, specially constructed for this study (Figure 3-5). It was designed to funnel all runoff into a 15-inch diameter concrete pipe leading to a leaching catch basin. Bacteriological samples were collected as runoff passed through the road grate of the solid bottom basin. Runoff water samples for chemical analysis were obtained by an automatic water sampler with the intake strainer secured at the upstream invert of the connecting 15-inch pipe. Flow measurements of the runoff were taken utilizing a remote sensing recording flowmeter with the sensor secured to the invert of the 15-inch pipe, two pipe diameters from the end of the pipe. Runoff then entered the leaching catch basin.

Depending upon the duration and/or intensity of the storm event the storage/leaching capacity of the catch basin could be exceeded. At that time samples of the basin effluent would be collected. Effluent water samples for chemical analysis were obtained using a second automatic water sampler with the intake strainer secured at the upstream invert of a 15-inch diameter concrete pipe leading to a main line leaching pool. Flow measurements of the basin effluent were taken by a second remote sensing flowmeter with the sensor secured to the pipe invert two pipe diameters from the end of the pipe connecting the catch basin and leaching pool. Bacteriological water samples were manually collected as the basin effluent exited from the connecting pipe and cascaded into the main line leaching pool.

A third sampling location, outfitted with an automatic water sampler and remote sensing flowmeter, was located in the 42-inch diameter main line drainage area. Sample collection was never performed at this sampling location because the storm events surveyed at this study site were not of sufficient intensity or duration to produce an overflow of the entire drainage system.

3.1.2.1. Equipment. Original field sampling protocols had specified that field personnel could respond within one hour of the onset of a storm event for surveys conducted at the Bayville study site. It had been planned that automatic sampling equipment would initiate sample collection in conjunction with automatic recording flow meters. However, experience gained during the first few attempts at automated sample collection indicated that collection of samples from the beginning of the storm event could only be guaranteed if field personnel were on site prior to the onset of the storm event.

Samples for physical and chemical analyses of stormwater runoff were obtained primarily using ISCO automatic sequential samples (Model 2100).

Samples for bacteriological analysis were manually obtained using sterile 125 ml Wheaton glass bottles. Runoff flows were measured using Model #265 Marsh-McBirney Velocity Modified Flow Meters.

3.1.2.2. Sampling Procedures. Field personnel arrived at the study site prior to the beginning of an anticipated storm event. Preparatory activities involved setting out rain collection apparatus, marking the chart on the automatic recording rain gage (located approximately ½ mile from the sampling location at a municipal building) and correcting the timing if necessary, marking sample containers, checking the proper operation of the automatic water samplers and flowmeters, and removing any accumulated debris from drainage structures, such as leaves and small branches that might obstruct runoff flow.

The automatic samplers were programmed to collect three successive one-liter discrete samples in order to provide sufficient volume for analysis of all parameters. The discrete samples were manually blended at a later time during the survey. The automatic water sampler was actuated by a liquid level sensor and programmed to collect the three-bottle sequence at fixed time intervals. In actual field operation, because of the very rapid response time of the drainage area, it was frequently necessary for personnel to manually activate the sampler sequence so that representative samples of the runoff hydrograph could be obtained. Sampling of the catch basin overflow was accomplished in a similar fashion, except that the automatic sampler was activated on a volumetric flow basis via a contact closure in the complementary flowmeter. The sampler was programmed to take a three-bottle sequence for every thousand gallons of water discharged from the catch basin to the leaching pool.

Sample collection of overflow from the entire drainage system never occurred during the storm events surveyed at this study site. Samples of an overflow from the downstream leaching pool receiving the overflow from the evaluated catch basin were obtained during two storm event surveys. These samples, obtained for bacteriological and chemical analyses, were collected by manual means only. Flow measurements were assumed to be roughly equivalent to those being recorded for the catch basin effluent entering the leaching pool. Overflow from the leaching pool continued only so long as catch basin effluent entered the leaching pool. During the period that the Perry Avenue drainage system was being evaluated, there was evidence of complete system overflow on only two or three occasions.

Table 3-1 lists the number and type of samples collected for analysis. Bacteriological samples were stored on ice in insulated coolers. Samples for chemical analysis, if collected by automatic sampler, were manually blended and split into a two-liter (½ gallon) and three one-half pint aliquots. The half gallon samples were stored on ice, without preservatives. Half-pint samples were preserved with sulfuric or nitric acid as required, and stored on ice in insulated coolers. Table 3-2 lists the pollutant parameters analyzed, both at this site and at the Unqua Pond site, together with sample volumes and preservation requirements. Samples were periodically delivered to the Nassau County Department of Health laboratory, Hempstead, N.Y., for analysis. The analysis methods employed followed the recommendations of the *Quality Assurance Project Plan* that was prepared for the Nassau Suffolk Urban Runoff Study (Guerrera, 1981).

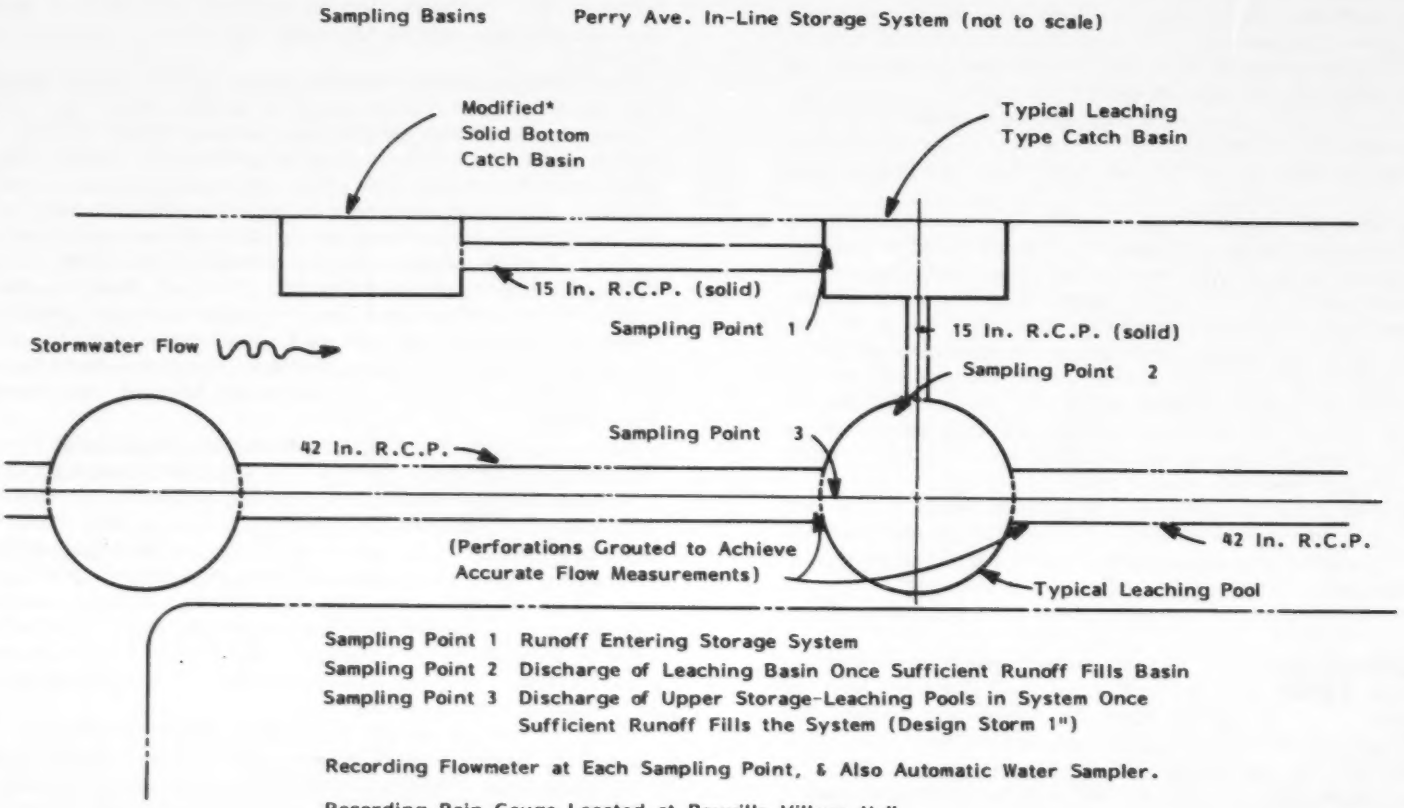


FIGURE 3-5 *Sampling basins In-Line storage system: Perry Avenue, Bayville*

Table 3-1

PERRY AVENUE, BAYVILLE
STORMWATER RUNOFF SAMPLING PROGRAM

Date	Source: Precipitation	Source: Runoff	Source: Catch Basin Effluent	Source: Discharge from Leaching Pool
2-19 & 20-81	1S	26B,11S	5B,2S	
2-23 & 24-81		15B, 6S	8B,4S	
3-30-81		5B, 1S		
4-14-81		13B, 6S	5B,1S	
5-15 & 16-81	1S	25B,11S	9B,4S	1B,1S
6-2-81	1S	6B, 5S		
7-29-81	1S	4B, 1S		
8-8-81		9B, 6S		
9-8-81	1S	20B, 7S	15B,7S	2B,2S
10-23 & 24-81	1S	25B, 6S	16B,5S	

Legend: S. Standard inorganic chemical analyses
B. Bacteriological analyses

3.1.3. Characteristics of Sampled Storms. Ten storm events were surveyed at the Bayville in-line storage drainage system study site. Analytical water quality data (bacteriological, inorganic chemical) were evaluated for eight of the ten storm events. Data for the two remaining events (2/19-20/81 and 4/14/81) could not be used because of the absence of corresponding flow data. Malfunction of electronic components in one of the flowmeters measuring runoff into the instrumented catch basin occurred during the first event surveyed at this site. Following repair, the unit performed satisfactorily. Additional difficulties in obtaining flow data were encountered because of the necessity to switch the velocity range setting control on the flow measuring units in response to the very rapid changes in runoff volume from the contributing 1.17-acre drainage area. The slow response time of the units to these changes made the collection of a continuous flow record difficult and at times impossible. This problem was partially rectified through the use of calibrated weirs positioned in the influent and effluent pipes of the leaching catch basin. Nevertheless, it should be noted that discrepancies in recorded flows may have affected some of the calculated values of the runoff coefficients, event mean concentrations (EMC), loadings and removal efficiencies.

One storm event was surveyed in autumn, two in winter, four in spring and three in summer.

Few events were sampled in the winter because of the need to avoid snow and ice melt contributing to runoff, and due to consideration for the safety of field personnel. Fall survey activity at this site was limited, to permit increased effort at the Massapequa study site.

Table 3-2

BAYVILLE AND MASSAPEQUA STUDY SITE
RUNOFF POLLUTANT CONSTITUENTS

Sample Volume	Preservation	Pollutant Parameters Analyzed
125 ml	4°C	Total Coliform Bacteria Fecal Coliform Bacteria Fecal Streptococcal Bacteria
0.5 gal.	4°C	Biological Oxygen Demand (BOD)
0.5 gal.	4°C	Total Suspended Solids Chlorides Chemical Oxygen Demand (COD) Ammonia (NH_3 – N) Nitrate (NO_3 – N) Nitrite (NO_2 – N) Total Alkalinity pH Color Turbidity Specific Conductance Ion Balance
0.5 pt.	pH < 2 (H_2SO_4)	Total Kjeldahl Nitrogen Total Phosphate (PO_4 – P)
0.5 pt.	pH < 2 (HNO_3)	Lead, Total Chromium, Arsenic, Cadmium
0.5 pt.	4°C	Total Organic Carbon (TOC)

Table 3-3 lists some of the storm-event characteristics for eight of the ten storms surveyed, including storm duration, total amount of precipitation, duration of precipitation, number of antecedent dry days, average intensity of precipitation per hour and per quarter hour and maximum observed intensity in one hour and in a quarter hour. Total precipitation amounts ranged from 0.10 inch to 1.34 inches. The mean storm volume for Long Island is approximately 0.43 inch and mean duration about six hours. In 38 percent of the surveyed storm events, total rainfall was less than the historical mean.

Table 3-3

PERRY AVENUE, BAYVILLE
STORM-EVENT CHARACTERISTICS

Date	Event Duration (hours)	Total Precipitation (inches)	Actual Duration of Precipitation (hours)	Antecedent Dry Days (≤ 0.1 inch)	Average + Precipitation (hr./15 min.)	Observed Max. Precipitation (hr./15 min.)
2-23-81	7.5	0.87	5.5	2.5	.16/.04	.38/.11
3-30-81	6.25	0.31	4.5	3.3	.07/.02	.11/.04
5-15-81	6.25	1.34	3.75	3.1	.36/.09	1.09/.45
6-2-81	6.0	0.50	5.25	4.0	.10/.02	.17/.05
7-29-81	2.5	0.10	1.25	1.8	.08/.02	.08/.04
8-8-81	3.5	0.24	3.25	10.1	.07/.02	.12/.04
9-8-81	4.5	1.01	4.0	6.8	.25/.06	.61/.27
10-23-81	11.5	0.97	11.0	4.5	.09/.02	.15/.05

+ For period of actual precipitation only.

Hourly rainfall intensities of sampled storm events ranged from 0.07 to 0.36 inch per hour. The historical mean intensity for the region is about 0.08 inch per hour. Thirty-eight percent of the sampled storm events had an average intensity equal to or less than the historical mean.

3.1.4 Analysis of Data

3.1.4.1. Description of In-line Storage Leaching Drainage System. The stormwater runoff retention drainage system that was constructed at Perry Avenue comprises a series of interconnected catch basins, leaching pools, and associated piping. Leaching catch basins, of which there are 21, are constructed of two six-foot diameter, four-foot high reinforced concrete rings. The lower ring is perforated, sits directly on virgin subsoil, and is collared with coarse gravel. Each catch basin has a concrete slab cover that accommodates a standard cast iron road grate/curb inlet. The 31 leaching pools are constructed of three ten-foot diameter reinforced concrete rings, the two lower rings perforated, set directly into the subsoil. Interconnecting reinforced perforated and non-perforated concrete pipe ranging in diameter from 15 inches to 42 inches are utilized between catch basins and leaching pools and between successive leaching pools. Figure 3-6 provides a schematic of the arrangement of the drainage system components.

Stormwater runoff first enters the leaching catch basins, which are located along the length of the thoroughfare, through the curb inlets and/or road grates. Each basin provides approximately 225 cubic feet of storage volume. Should the volume of runoff exceed the retention capacity of the catch basin, the excess volume overflows to a leaching pool through a 15-inch upward-sloped pipe. As each ten-foot-diameter leaching pool fills to capacity (approximately 1100 cubic feet per pool), the excess volume of runoff overlfows to the next downstream leaching pool. All leaching pools are connected in series and are constructed with the effluent pipe invert at a higher elevation than that of the influent pipe, thereby providing additional storage and leaching capacity within the upstream pipe. Interconnecting pipes range in diameter from 24 inches to 42 inches and are perforated.

The drainage system is designed to discharge runoff volumes in excess of the system storage/leaching capacity to Mill Neck Creek (Figure 3-3). The latter is part of the larger Oyster Bay system.

Construction of this drainage system was planned to be completed in three phases and was designed to provide a total retention or storage capacity of 107,000 cubic feet. Only two of the three proposed subsections were actually constructed. The resultant storage capacity provided by the system is approximately 86,000 cubic feet or 80 percent of the original design capacity.

3.1.4.2. Load Reduction Analysis. Event mean concentrations for the three bacterial indicator groups were calculated for eight events. Values were obtained for the stormwater runoff (inflow to catch basin) and for the overflow volume from the catch basin (discharge). This data is presented in Table 3-4. A comparison of these influent (inflow) and effluent (discharge) EMC's indicates that no improvement in bacterial concentration is achieved through temporary retention of the runoff in the catch basin. In fact, what appears to occur, based upon the limited data, is the bacteriological degradation of water quality. There is insufficient data upon which to draw conclusions as to how or why the concentrations of bacteria appear to increase. Possible explanations include resuspension of bacteria resident in, or on, the sediments trapped in the catch basin, either retained from previous storm events or multiplying in the moist, organically enriched sediment.

Table 3-5 presents values for the bacterial loads entering the catch basin during each of the eight surveyed events and the bacterial load in the discharge from the catch basin for those events when overflow occurred. The fecal coliform load increased during two events, total coliform load increased during three events, and the fecal streptococci load increased during three events. As stated previously, the quantity of data available is deemed to be inadequate for reaching any conclusions. Although it appears that the leaching catch basin does not uniformly provide attenuation of bacterial load during periods of basin overflow, the overflow runoff volume containing the bacteria enters a storage/recharge structure, the leaching pool, where under most conditions it is dissipated via infiltration to the ground.

Table 3-6 presents the ratios of fecal coliform to total coliform (FC/TC) and fecal coliform to fecal streptococci (FC/FS). The FC/TC ratio gives the fraction of the coliform organisms that are of fecal origin. The observed range varied from a high of 51 percent to a low of 2 percent, with a mean value of 12 percent. The major portion of the coliform bacteria in runoff generated in the

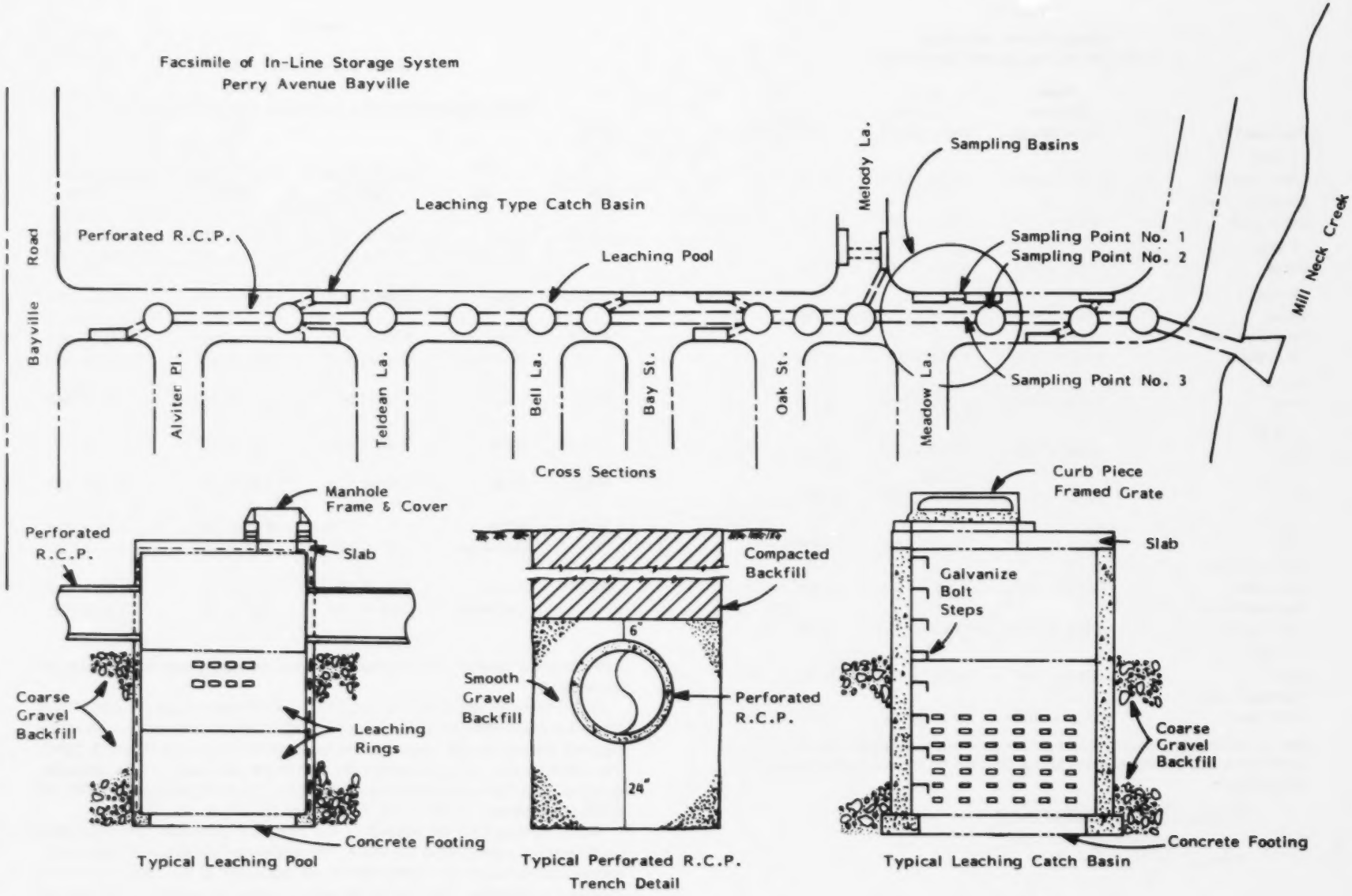


FIGURE 3-6 *Facsimile of In-Line storage system: Perry Avenue, Bayville*

Table 3-4

PERRY AVENUE, BAYVILLE
EVENT MEAN CONCENTRATIONS (EMC)

Date and Site	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Fecal Strep (MPN/100 ml)
2-23-81			
Inflow (Runoff)	0.281×10^4	0.101×10^3	0.192×10^4
Discharge from Catch Basin	0.415×10^4	0.273×10^3	0.884×10^4
3-30-81			
Inflow	0.142×10^4	0.330×10^2	0.394×10^4
5-15-81			
Inflow	0.380×10^5	0.652×10^4	0.389×10^5
Discharge from Catch Basin	0.450×10^5	0.657×10^4	0.522×10^5
6-2-81			
Inflow	0.155×10^6	0.201×10^5	0.240×10^6
7-29-81			
Inflow	0.424×10^6	0.317×10^5	0.281×10^6
8-8-81			
Inflow	0.330×10^6	0.118×10^5	0.742×10^5
9-8-81			
Inflow	0.151×10^6	0.152×10^5	0.695×10^5
Discharge from Catch Basin	0.345×10^6	0.182×10^5	0.989×10^5
Discharge from Leaching Pool	0.108×10^7	0.383×10^4	0.191×10^6
10-23-81			
Inflow	0.251×10^4	0.127×10^4	0.174×10^5
Discharge from Catch Basin	0.505×10^6	0.807×10^4	0.184×10^5

EMC is calculated by dividing the total quantity of the pollutant of interest carried in runoff by the total quantity of runoff during the surveyed portion of a storm event using the equation:

$$EMC = \frac{\Sigma \frac{(t_{N+1} - t_N)(C_N Q_N + C_{N+1} Q_{N+1})}{2}}{\Sigma \frac{(t_{N+1} - t_N)(Q_N + Q_{N+1})}{2}}$$

where C is the measured concentration of pollutant in collected samples, Q is the recorded flow at time of corresponding sample collection, and t is time at which sample was collected.

Table 3-5

PERRY AVENUE, BAYVILLE
BATERIOLOGICAL LOADS
TOTAL COLIFORM, FECAL COLIFORM, FECAL STREPTOCOCCI

Date	Site	Total Coliform (MPN)	Fecal Coliform (MPN)	Fecal Streptococci (MPN)
2-23-81	Inflow	6.18×10^9	2.22×10^8	4.22×10^9
	Discharge	7.19×10^9	4.73×10^8	1.53×10^{10}
3-30-81	Inflow	1.84×10^8	4.27×10^8	5.10×10^8
5-15-81	Inflow	8.31×10^{10}	1.43×10^{10}	8.50×10^{10}
	Discharge	2.18×10^{10}	3.18×10^9	2.52×10^{10}
6-2-81	Inflow	1.64×10^{10}	2.12×10^9	2.54×10^{10}
7-29-81	Inflow	4.92×10^9	3.68×10^8	3.26×10^9
8-8-81	Inflow	3.62×10^{10}	1.29×10^9	8.13×10^9
9-8-81	Inflow	8.14×10^{10}	8.19×10^9	3.75×10^{10}
	Discharge	1.37×10^{11}	7.24×10^9	3.94×10^{10}
10-23-81	Inflow	4.23×10^8	2.14×10^8	2.93×10^9
	Discharge	9.04×10^9	1.44×10^9	3.29×10^9

Bayville study area is of non-fecal origin, presumably being saprophytic soil bacteria.

FC/FS ratios ranged from 0.219 to 0.008, with a mean value of 0.091. These ratios are well below the upper limit of 0.7, which implicates non-human warm-blooded animals as the source of the fecal coliform bacteria (Mallard, 1980). The ratios for Bayville when compared with those calculated for the Massapequa and Deer Park study sites come closest to the 0.02 (Geldreich, 1968) and 0.002 (Koppelman, 1978) FC/FS values cited for dog feces.

Storm loading data for several of the inorganic chemical runoff pollutant parameters is presented in Table 3-7. The suspended solids runoff loading factors indicated tend to be higher than those measured at the other two control measure study sites. This can be at least partially explained by the steeper slope of the topography. (40 feet per mile compared with 20 feet per mile for the south shore sites).

Table 3-6

PERRY AVENUE, BAYVILLE STUDY SITE
FECAL COLIFORM/TOTAL COLIFORM
FECAL COLIFORM/FECAL STREPTOCOCCI

Date	Fecal Coliform/Total Coliform Inflow	Fecal Coliform/Total Coliform Discharge	Fecal Coliform/Fecal Strep Inflow	Fecal Coliform/Fecal Strep Discharge
02-23-81	.036	.066	.053	.031
03-30-81	.023		.008	
05-15-81	.017	.146	.017	.126
06-02-81	.130		.084	
07-29-81	.075		.113	
08-08-81	.036		.159	
09-08-81	.101	.053	.219	.184
10-23-81	.506	.160	.073	.439
Median	.056	.106	.079	.155
Mean	.116	.106	.091	.195

Table 3-7

PERRY AVENUE, BAYVILLE
SELECTED CHEMICAL PARAMETERS

Date	Rainfall (inches)	Wetfall (lbs/acre)	Runoff EMC (mg/l)	Unit Load (lbs/acre)	Load Factor (lbs/acre/in)
Parameter: Total Suspended Solids					
02-23-81	0.87	0.394	71.8	29.883	34.348
05-15-81	1.34	0.607	1981.7	797.350	595.037
06-02-81	0.50	0.113	113.0	3.222	6.444
08-08-81	0.24	+	143.0	3.563	14.846
09-08-81	1.01	0.458	225.0	24.588	24.345
10-23-81	0.97	0.439	35.7	1.132	1.167
Parameter: Total Phosphate - as P					
02-23-81	0.87	0.014	0.014	0.224	0.257
05-15-81	1.34	0.009	1.464	0.689	0.514
06-02-81	0.50	+	0.324	0.009	0.018
08-08-81	0.24	+	0.626	0.016	0.067
09-08-81	1.01	0.047	0.533	0.058	0.057
10-23-81	0.97	0.002	0.275	0.010	0.010

Table 3-7 (Continued)

Date	Rainfall (inches)	Wetfall (lbs/acre)	Runoff EMC (mg/l)	Unit Load (lbs/acre)	Load Factor (lbs/acre/in)
Parameter: Total Kjeldahl Nitrogen - as N					
02-23-81	0.87	0.020	0.0503	0.209	0.240
05-15-81	1.34	0.173	2.925	1.177	0.878
06-02-81	0.50	+	1.080	0.032	0.064
08-08-81	0.24	+	1.860	0.071	0.296
09-08-81	1.01	0.053	0.983	0.114	0.113
10-23-81	0.97	0.073	2.834	0.090	0.093
Parameter: Nitrate—as N					
02-23-81	0.87	0.0099	0.0698	0.029	0.033
05-15-81	1.34	0.3278	0.2113	0.044	0.033
06-02-81	0.50	0.0374	0.3790	0.011	0.022
08-08-81	0.24	+	1.20	0.030	0.125
09-08-81	1.01	0.0457	0.0443	0.005	0.005
10-23-81	0.97	0.0593	0.2142	0.007	0.007
Parameter: Nitrite - as N					
02-23-81	0.87	0.0002	0.0127	0.0053	0.0061
05-15-81	1.34	0.0042	0.2113	0.0850	0.0634
06-02-81	0.50	0.0006	0.0414	0.0062	0.0124
08-08-81	0.24	+	0.1320	0.0032	0.0133
09-08-81	1.01	0.0005	0.0080	0.0009	0.0009
10-23-81	0.97	0.0009	0.0231	0.0007	0.0007
Parameter: Ammonia - as N					
02-23-81	0.87	0.0059	0.0896	0.044	0.051
05-15-81	1.34	0.0668	-	-	-
06-02-81	0.50	0.0147	0.0333	0.001	0.002
08-08-81	0.24	+	0.2110	0.005	0.020
09-08-81	1.01	0.0022	0.0447	0.005	0.005
10-23-81	0.97	0.0220	-	-	-

+ No sample obtained.
- Data not analyzed.

The highest measured value of 595 lbs/acre-in is attributable to construction activity that had been occurring near the study site. The intensity of this particular storm event was also unusually high (observed maximum hourly intensity of 1.09 inches). That may have caused the introduction of sediment-laden runoff from the adjacent drainage area into the study site area as well. Similarly, the highest indicated load factors for total phosphate, Kjeldahl nitrogen, and nitrite-nitrogen occurred during this storm event.

Load factors for the Bayville area fall within the same ranges of values as those observed at the other two study sites. There is insufficient data for the Bayville site to make an assessment of the effect of seasonal variation or evaluate the effects of storm intensity, duration and antecedent conditions upon the magnitudes of the runoff pollutant loads.

3.1.4.3. Control Measure Effectiveness. The original drainage system design capacity of 107,000 cubic feet was based upon containing the runoff associated with a one-inch rainfall and using a very conservative runoff coefficient value of 0.45. The design did not assign a value to runoff volume reduction resulting from leaching from the system. The volumetric capacity of the as-built system (86,000 cubic feet) is sufficient to contain the runoff generated from a one-inch storm if a runoff coefficient of 0.36 is assumed. Impervious surfaces comprise 15 percent of the drainage area. If the runoff coefficient is equal to the percentage of impervious surface within the drainage area, then the system is capable of retaining runoff generated during a 2.4 inch storm event. Table 3-8 lists the calculated runoff coefficients from the eight storm events evaluated at the Bayville study site. If the highest and lowest values are disregarded because of difficulties encountered with the recording flowmeter during these events, the mean value for the remaining six events is 0.27. The calculated values are based upon measurements taken at a leaching catch basin whose tributary drainage area was determined to be 1.17 acres. While the distribution of impervious areas within the 1.17 acre area may not be totally representative of the entire 66 acre drainage area served by the storage/retention drainage system, the calculated mean value of 0.27 compares favorably with the runoff coefficients determined for the Massapequa and Deer Park study sites, where the land use is also primarily medium-density residential development. The relatively steep slope of this drainage area (40 feet/mile) probably allows for some contribution of runoff from pervious areas such as lawns, which tends to increase the runoff coefficient.

The maximum storm event rainfall that could be retained by the storage capacity of the drainage system structures (86,000 cubic feet) when the calculated runoff coefficient value of 0.27 is applied to the drainage area (66 acres) is 1.33 inches, assuming no concurrent loss due to exfiltration from the system. Historical data shows that total rainfall volume per storm has a gamma distribution (USEPA, 1979). Knowing the mean precipitation, coefficient of variation, and mean interval between storm event midpoints, the probability of exceeding a rainfall of a given value and the expected number of such occurrences per year can be estimated.

For the Nassau-Suffolk region, the mean storm volume is 0.43 inch, coefficient of variation approximately 1.4, and mean interval between storms 88 hours. Given these values, the probability of exceeding a 1.33-inch rainfall is 7 percent. Since the number of storm events expected to occur per year is 100, seven storm events can be expected to produce a total rainfall of more than 1.33 inches. Therefore, 93 percent of all storm events in this region would produce 1.33 inches or less of rain, and the runoff generated during these events would be completely retained by the Bayville drainage system. A storm event producing this amount of rainfall in one hour has a two-year return period. If this amount occurs over longer time periods, the return period decreases.

During the period that this drainage system has been in operation, there has been evidence of the storage capacity being exceeded on only a few occasions, i.e., during storm events of very high intensity (measured in inches per hour) and very short duration (measured in minutes).

In calculating total retention capacity of the in-line drainage system, the rate at which runoff can be recharged to groundwater during a storm event via the system components must be considered. Table 3-9 presents the measured leaching rates for two of the leaching structures, a catch basin and a leaching pool. Average rates for each structure are 6.4 and 25.1 cubic feet per hour, respectively. Application of these leaching rates yields a total leaching capacity of 900 cubic feet per hour for all basins and pools in the system, which equals the runoff generated by a rainfall of about 0.014 inch/hour, using a runoff coefficient of $C = 0.27$. This calculation assumes that all leaching structures are completely filled.

It should be noted that the two structures that were evaluated are located in an area possessing the worst recharge conditions within the system since the groundwater level in this area is just below the bottom of the catch basin and is actually intercepted by the leaching pool as evidenced by the presence of standing water at all times. This leaching pool maintains a standing water level during dry weather of approximately eight feet, equivalent to a volume of 629 cubic feet. Therefore, the calculated leaching rates are assumed to be conservative when applied to the remaining system structures where the structures are further removed from groundwater due to the steeply sloping topography.

In practical terms, it would appear that the minimum depth to groundwater below leaching catch basins should be no less than two feet when the substratum consists of coarse material (Lawler, Matusky and Skelly, 1982). Furthermore, according to the project's engineering consultant:

> The effectiveness of the leaching catch basin is dependent upon a high hydraulic conductivity or infiltration capacity in the soil and a reasonable depth to groundwater. In general, the high conductivity capacity must extend through the soil mass to allow the leached runoff to discharge freely to the groundwater. The most effective leaching will occur from catch basins which are located above the groundwater table in a porous soil strata. (See Appendix D.)

Table 3-8

PERRY AVENUE, BAYVILLE
PRECIPITATION, RUNOFF AND RUNOFF COEFFICIENT

Date and Site	Rainfall (inches)	Runoff Volume (cu. ft.)	Runoff Coefficient
2-23-81			
Inflow (Runoff)	.87	7762	2.098
Discharge from Catch Basin		6115	
3-30-81			
Inflow	.31	457	0.331
5-15-81			
Inflow	1.34	7720	0.181
Discharge from Catch Basin		1707	
6-2-81			
Inflow	.50	373	0.185
7-29-81			
Inflow	.10	41	0.103
8-8-81			
Inflow	.24	387	0.385
9-8-81			
Inflow	1.01	1903	0.447
Discharge from Catch Basin		1405	
Discharge from *Leaching Pool*			
10-23-81			
Inflow	.97	595	0.028
Discharge from Catch Basin		632	
		Average*	0.272

* Average does not include first and last storm events.

Table 3-9

PERRY AVENUE, BAYVILLE
INFILTRATION RATE OBSERVATIONS

Date	Rainfall (inches)	Recharge Structure	Diameter (feet)	Time Interval of Observation (hours)	Decrease in Water Elevation (inches)	Infiltration Rate (cu. ft. per hour)
09-08-81	1.01	Catch Basin	6	1.75	4.5	6.06
		Leaching Pool	10	1.75	10.0	37.40
10-06-81	0.75	Catch Basin	6	2.5	7.0	6.06
		Catch Basin	6	1.0	4.25	10.01
		Catch Basin	6	1.0	3.50	8.25
11-06-81	0.75	Leaching Pool	10	2.5	11.0	28.80
		Leaching Pool	10	1.0	1.5	9.82
01-04-82	3.0	Catch Basin	6	5.0	10.0	4.71
		Catch Basin	6	12.5	15.0	2.83
		Leaching Pool	10	2.0	7.5	24.54

The leaching rates previously cited do not accurately reflect the permeability of the drainage area's underlying sand/gravel in which the system structures are situated. An assessment of the potential leaching capacity of the system can be made by utilizing an infiltration rate characteristic of the area's subsoils. Seaburn and Aronson (1974) evaluated recharge basin infiltration rates in the Long Island region. It was determined that water percolation into the subsoil occurred at rates of 0.2 to 0.9 cubic feet per hour per square foot of soil surface. If the approximately midpoint rate of 0.5 cubic feet per hour is selected as representative of the expected rate for the substrata in Bayville,

an estimate can be made of the additional capacity of the drainage system due to the volume of runoff recharged to groundwater. Infiltration of runoff can occur in leaching catch basins, leaching pools, and in the lengths of perforated pipe that interconnect catch basins and leaching pools.

The system's leaching capacity, assuming an infiltration rate of 0.5 cubic feet per hour per square foot of effective structure area, and assuming further that the drainage system is filled to its volumetric capacity, is equivalent to a system infiltration rate of 17,200 cubic feet per hour. This would allow continuous infiltration of runoff from a storm having a sustained intensity of 0.27 inch/hour. The maximum storm event occuring in one hour that would not exceed the total system capacity would be 1.6 inches (1.33 inches-storage plus .27 inch-infiltration) which would generate a runoff volume of 103,000 cubic feet (C = 0.27). A 1.6 inch storm occurring over one hour has a return period of greater than two years. In a gamma distribution, where the mean storm volume is 0.43 inch and the coefficient of variation (C_v) is 1.4, five percent of storm events occurring in a year would be expected to exceed 1.6 inches. Runoff from storm events greater than 1.6 inches occurring over a period of hours could be retained by the system. Naturally, such an occurrence is governed by the duration and intensity of the storm event.

A methodology has been developed, which further substantiates the validity of the preceding assessment of the expected flow reduction capability of the Perry Avenue system. This methodology is presented in a screening analysis procedure outlined in a recent draft report (USEPA, 1982). One of the report's basic purposes is to provide a means of making a rapid assessment of the removal capabilities of a recharge/storage device subjected to storm events, without requiring more complex simulation schemes needing a digital computer. The analysis assumes that the runoff which percolates into the ground is removed, as are its associated pollutants.

Since the occurrence of storm events are basically random in nature, the procedure provides a means for calculating the average long-term reduction of runoff volume achieved through the two mechanisms which operate within the Perry Avenue system — percolation and retention or storage. In order to do this, certain information concerning rainfall statistics must be available. Basically this consists of the mean values and coefficients of variation (standard deviation/mean) of rainfall intensity, volume, duration and interval between rain events. In addition, catchment area, runoff coefficient, soil percolation rate and device volume and surface area provided for percolation must be specified.

For the Perry Avenue system, calculated long term reductions for percolation and storage were determined to be 93.5 and 89 percent respectively, using the USEPA methodology and Long Island rainfall statistics. The overall removal by the system, which is a function of that associated with both percolation and storage, was determined to be 99.3 percent. For the Nassau-Suffolk region, one hundred storm events occur, on the average, during a given year. Based upon the above analysis, the system can be expected to overflow once every 1.4 years.

The observations of the occurrence of system overflow cited earlier substantiate the conclusion that this in-line storage/recharge drainage system is capable of retaining runoff generated during almost all precipitation events occurring in this region. For unusual storm events, which produce runoff in excess of the storage/leaching capacity, the volume discharged to the estuarine waters is attenuated by at least the storage capacity of the system.

3.2 UNQUA POND, MASSAPEQUA SITE

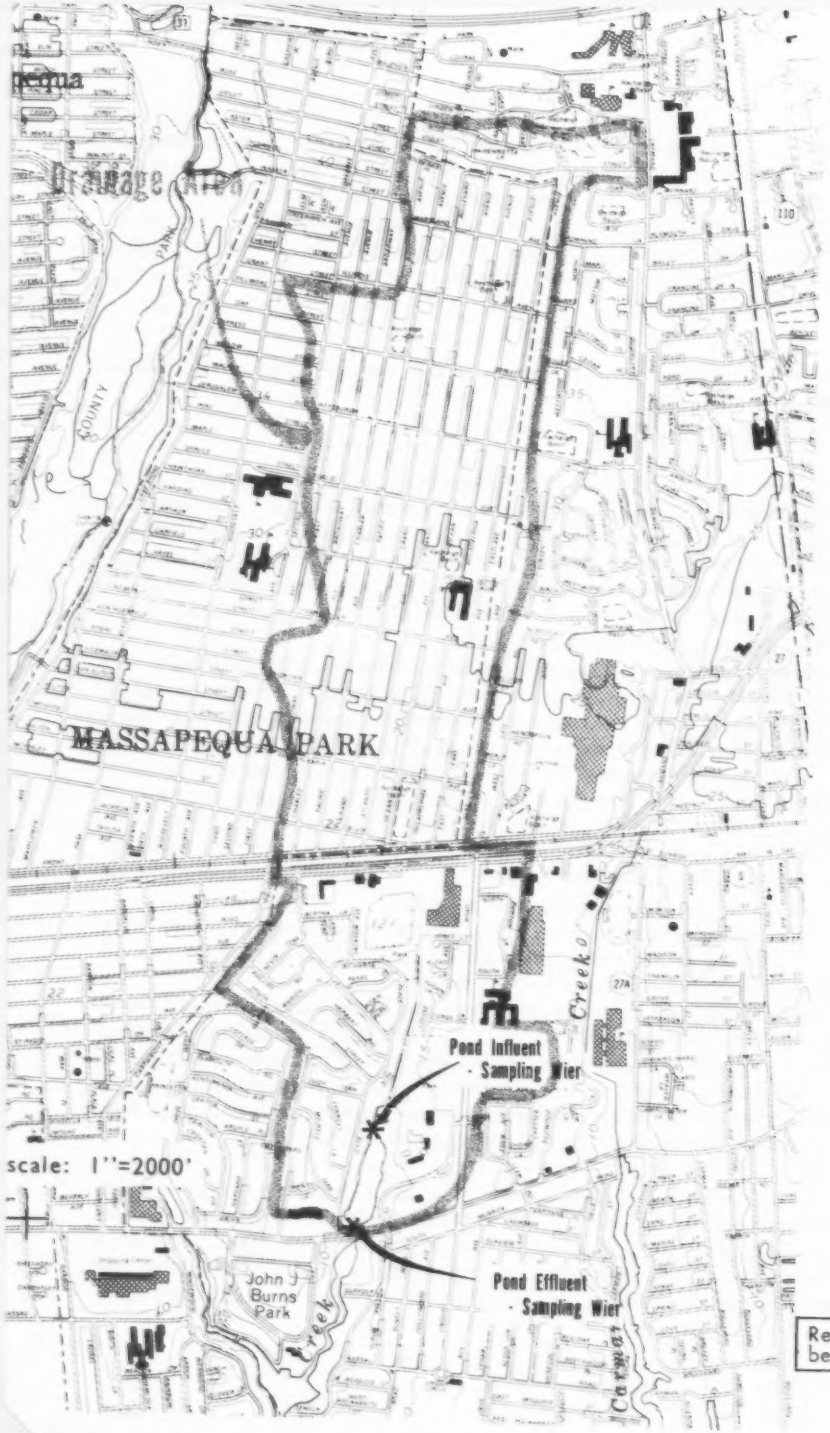
3.2.1. Site Description. The Unqua Pond, Massapequa study site comprises a primary drainage area of 298.5 acres and a secondary drainage area of an additional 451 acres that contributes varying amounts of stormwater runoff during more intense storm events as five upstream stormwater recharge basins exceed their storage/infiltration capacity. Therefore, the maximum contributing drainage area is 749.5 acres. The northern 451 acres lie within the Incorporated Village of Massapequa Park. The southern 298.5 acres are located in Massapequa, an unincorporated area in the Town of Oyster Bay. The study area is bounded on the north by Linden Street from Broadway to Carman Road; on the east by Park Lane and Unqua Road; on the south by Merrick Road; and on the west by a topographical divide running between 2nd Avenue and Broadway.

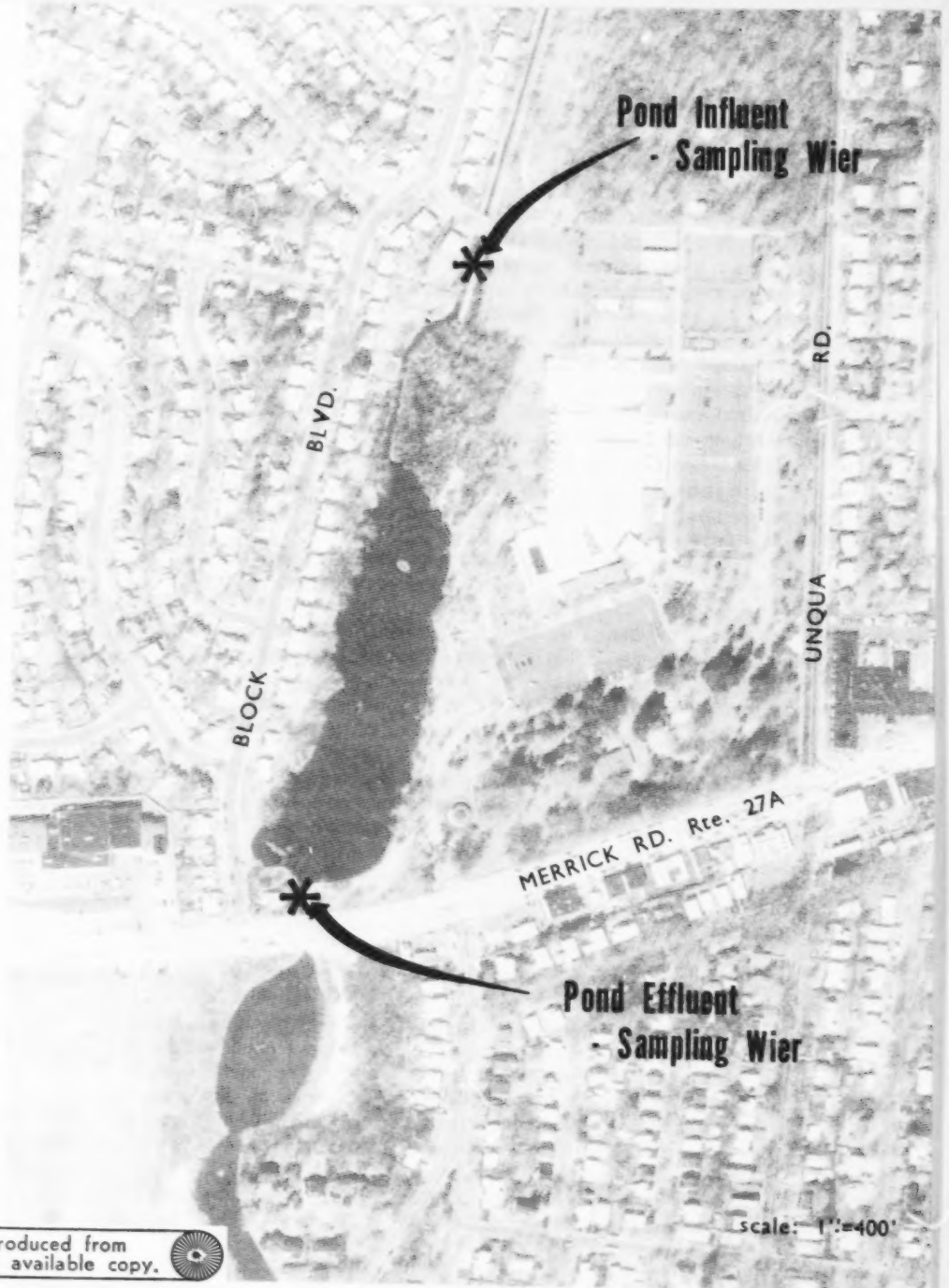
Figure 3-7 shows a topographic map of the drainage area together with an aerial photograph of the Pond.

Stormwater runoff from this drainage area finally discharges to Jones Creek, a tidal creek of South Oyster Bay. South Oyster Bay is contiguous with the Great South Bay to the east in Suffolk County, and East Bay to the west in Nassau County. A portion of South Oyster Bay is currently certified for shellfish harvesting; however, that portion of the embayment adjacent to the mainland shoreline is uncertified. South Oyster Bay receives stormwater runoff not only from Jones Creek but also from additional stream-drainage channels and from direct overland runoff from adjacent shoreline peninsulas.

South Oyster Bay marine receiving water quality data obtained at the point of convergence with Jones Creek during the period October 1979 through September 1980 exhibited a geometric mean total coliform density for wet weather samples of 240MPN/100 ml, with 43 percent of wet weather samples greater than 330 MPN/100 ml. For the combined years of 1980-1981, the geometric mean for wet weather samples was 430/100 ml with 57 percent greater than 330 MPN/100 ml.

The major land use within the Unqua Pond study area is medium density residential development, generally single family homes on building lots of at least 60 ft. by 100 ft. Approximately 85 percent of the primary drainage area, and 94 percent of the secondary drainage area consists of this use. About five percent of the primary area is devoted to commercial uses; ten percent is





Reproduced from
best available copy.

FIGURE 3-7 *Topographic map and aerial photograph of Unqua Pond, Massapequa*

open space. Some six percent of the secondary area is dedicated to educational and municipal use.

Approximately 17 percent of the land within the entire drainage area has paving or other impervious surface. The study site, with a gentle slope of 20 ft. per mile, is topographically representative of the glacial outwash plain that forms much of the southern half of Long Island.

The drainage area soils have been classified as belonging to the Urban Land — Riverhead complex. The Riverhead complex consists of deep, well drained soils on outwash plains and valley trains. They were formed in relatively gravel-free deposits overlying stratified sand and gravel. Typically these soils have a brown to dark brown sandy loam surface layer 12 inches thick. The subsoil is strong brown sandy loam to yellowish brown loamy sand that is gravelly below 32 inches. The substratum from 35 to 65 inches is brown and very pale brown stratified sand containing thin gravel layers. Permeability is moderately rapid in the upper loamy material and very rapid in the underlying sand and gravel. The drainage area is nearly level throughout. (USDA, 1976)

3.2.2. Sampling Program. Storm event runoff sampling was accomplished by personnel of the Bureau of Water Pollution Control, Nassau County Department of Health.

Sampling at the Massapequa study sites required the deployment of field personnel prior to the occurrence of storm events. To facilitate early deployment of field crew(s), weather broadcasts, primarily NOAA weather radio broadcasts originating in New York City, were monitored when weather patterns indicated the potential for the occurrence of significant rainfall.

3.2.2.1 Equipment. Sample collection at the Unqua Pond study site, at both pond influent and effluent locations was accomplished using manual sampling techniques. Bacteriological indicator samples were collected in sterile 125 ml Wheaton glass bottles with ground glass stoppers. Samples to be analyzed for inorganic chemical and physical parameters were collected in one-half gallon and half pint Nalgene® brand linear polyethylene widemouth containers. To the extent possible, samples were collected across the width of the stream channel to give the most representative sample possible.

Concurrent with collection of each sample, flow measurements were taken utilizing calibrated staff gauges affixed to the walls of concrete box culverts conveying influent and effluent water streams. Calibration of staff gauges was accomplished through the use of rating curves. Extensive velocity and water depth measurements were made during runoff events using a Marsh-McBirney model "201" portable velocity-meter fitted with a top-setting wading rod. Volumetric flow rates were calculated using standard USGS methodology and calculated rates were used as data points in developing the rating curves.

3.2.2.2. Sampling Procedures. Prior to the onset of a storm event a field crew was deployed to the influent sampling location of the study site. Field personnel performed necessary preparatory activities including setting out rain collection apparatus, marking the chart on the automatic recording rain gauge (located at an adjacent Park building) and correcting the time if necessary, marking sample containers with the correct notations indicating site, sampling location, storm event being sampled, sample number, and a letter indicating the analyses to be performed on a sample. The following is an example of the marking sequence used.

Site:	Sample Location	Storm event at site	Sample in Series	TOC analysis
Unqua	Influent			
U	I	01	01	F

Sample collection during a runoff event commenced when stream flow increased to ten percent above baseflow and stopped when flow returned to approximately ten percent above baseflow, or occasionally for other reasons. Generally it was attempted to sample over the complete hydrograph of the runoff event. However, due to the long lag time in returning to baseflow at the effluent of the impoundment, the end point of sampling was usually determined by time expenditure considerations.

Background water samples of the stream baseflow at both the influent and effluent of the pond were taken as close to the onset of the storm event as possible. Once the storm event commenced, bacteriological samples were collected at a fixed time interval, usually set at fifteen minutes. Water samples to be analyzed for chemical and physical parameters were collected at a frequency dependent upon stage of hydrograph, rate of flow increase or decrease, and laboratory constraints. Sampling ceased at the influent when flow returned to approximately ten percent above starting baseflow. Sampling continued at the pond effluent location for up to forty-eight hours after the end of the runoff event, but at reduced frequency.

Bacteriological samples were stored on ice in insulated coolers. Samples for chemical analysis were preserved with sulfuric acid or nitric acid as required, and stored on ice in insulated coolers.

Accumulated samples were delivered to the Nassau County Department of Health Laboratory, Hempstead, N.Y., at intervals throughout the sampling period. Analyses were normally begun immediately upon delivery of samples to the laboratory. The methods used conformed to the recommendations of the *Quality Assurance Project Plan* that was prepared for the Long Island Segment of the Nationwide Urban Runoff study (Guerrera, 1981).

3.2.3. Description of Impoundment as a Control Measure. Unqua Pond, an impoundment located at the mouth of the Unqua River, has a surface area of 5.5 acres (average width of 200 ft., length approximately 1000 ft.), average depth of 3.3 ft., and a standing volume of approximately 784,000 cubic feet (ft^3). This pond is believed to have originated as a mill pond, constructed to pro-

vide water power for milling grains produced on surrounding farmland.

The source of dry weather flow (0.5 ft^3/second) of the Unqua River is the Upper Glacial or water table aquifer from which groundwater exfiltrates into the streambed at a point approximately one mile north of the impoundment. Effluent from the pond discharges to the estuarine waters of South Oyster Bay.

During wet weather, the impoundment can receive urban stormwater runoff from a 749 acre drainage basin. Of the 749 acres, 299 acres drain directly to the pond through a system of storm sewers. Runoff from the remainder of the drainage area, 451 acres, is directed to a series of five recharge basins, which retain varying volumes before contributing excess to storm sewers leading to the point of origin of the stream. The size of the contributing drainage area will vary depending upon the duration and/or intensity of storm events. For the purpose of data evaluation, the contributing drainage area was usually considered to be 299 acres. Some further determinations of runoff coefficients and load factors were also made utilizing the 749 acre drainage area. For most storm events, the contributing area is more than 299, but less than 749 acres. (299 acres 19.5 percent impervious, 451 acres 15.8 percent impervious, 749 acres 17 percent impervious). It should be pointed out that the primary objective of this part of the project was to evaluate the effectiveness of a pond in removing storm-related loads, particularly bacteriological ones, as indicated by the number of coliform bacteria. Thus the exact size of the contributing drainage area during any storm event was only of secondary interest. Evaluating an impoundment's ability to attenuate stormwater pollutant loads is important because many of the stream corridors in the Long Island region have one or more impoundments located along their length. Usually such impoundments are located at the mouth of the fresh water stream just landward of the point of discharge to estuarine water.

3.2.4. Characteristic of Sampled Storms. Eleven storm events were surveyed at the Unqua Pond, Massapequa study site during the course of the project. Five events were surveyed in autumn, one in winter, one in spring and four in summer. Winter survey activity was limited due to the presence of ice cover on the impoundment and the need to avoid the inclusion of snow/ice melt in the sampled runoff. Just one spring storm event was monitored at this site because of the necessity of redirecting survey activity to the Bayville study site.

Table 3-10 lists the dates of completed storm event surveys and the number and type of water samples collected for laboratory analysis during each event. Wetfall samples were obtained for nine of the eleven events.

Storm event characteristics for the surveyed storms are presented in Table 3-11. These include event duration, the total amount of precipitation per event, the period of time during which precipitation actually occurred, the antecedent dry period, average hourly and quarter hourly rainfall intensities, and maximum hourly and quarter hourly rainfall intensities. Total precipitation amounts for the eleven events surveyed ranged from 0.25 to 2.56 inches. The mean for these eleven events is 0.98 inch compared with the historical annual event mean rainfall of 0.43 inch. Three events produced precipitation less than or equal to his historical mean. Average hourly rainfall intensities of sampled storm events ranged from 0.07 to 0.27 inch per hour and maximum hourly intensities ranged from 0.09 to 0.86 inch per hour. The historical mean intensity for the region is approximately 0.076 inch per hour. One storm event out of the eleven surveyed had an intensity less than the historical mean.

Generally, the storms that were selected for survey activity were substantially larger than the average for all storm events occuring in the Nassau-Suffolk area. When the runoff volume generated by a small storm is a small fraction of the volume of the impoundment into which it flows, the effluent stream will tend to be made up primarily of water that was resident in the pond prior to the storm. For low intensity storm events the period of time over which sampling activity would have had to take place was deemed to be excessive and would have extended beyond the historical mean interval of 88 hours between storms. The occurrence of a subsequent storm event during an ongoing survey would result in the curtailment of the survey. Therefore survey efforts were concentrated on large storms that generated runoff volumes of sufficient magnitude to allow for shortened residence time of runoff influent in the impoundment.

Table 3-10

UNQUA POND, MASSAPEQUA
STORMWATER RUNOFF SAMPLING PROGRAM

	Source		
Date	Precipitation	Runoff	Control Measure Effluent
9-18-80	1S	9B,6S	9B,6S
9-25 & 26-80	1S	18B,18S	21B,17S
10-3 & 4-80	1S	34B,12S	29B,12 S
10-25 & 26-80	1S	71B,25S	43B,16S
11-17 & 18-80	1S	39B,12S	43B,16S
2-1,2 & 3-81	1S	54B,14S	49B,17S
7-1-81	1S	31B,8S	29B,8S
7-19 to 22-81	1S	57B,12S	78B,20S
9-15 to 19-81	2S	101B,25S	120B,26S
12-1 & 2-81		32B	46B
4-3 & 4-82		24B	46B

Legend: S. Standard inorganic chemical analyses.
B. Bacteriological analyses.

Table 3-11

UNQUA POND, MASSAPEQUA
STORM EVENT CHARACTERISTICS

Date	Event Duration (hours)	Total Precipitation (inch)	Actual Duration of Precipitation (hours)	Antecedent Dry Days ($\leq$ 0.1 in.)	Average+ Precipitation (hr/15 min.)	Observed Max. Precipitation (hr/15 min.)	Hour Max/ Hour Avg	15" Max/ 15" Avg
09-18-80	5.5	0.54	4.5	15.13	.12/.03	.30/.07	2.5	2.33
09-25-80	16.5	0.38	3.33	7.25	.11/.03	.22/.15	2.0	5.0
10-03-80	6.5	0.43	4.66	0.50	.09/.02	.09/.02	1.0	1.0
10-25-80	9.25	1.30	6.5	6.23	.20/.05	.45/.14	2.25	2.80
11-17-80	6.75	0.45	6.5	8.16	.07/.02	.13/.05	1.86	2.5
02-02-81	6.5	0.58	5.5	0.33	.11/.03	.13/.04	1.18	1.33
07-01-81	1.0	0.25	0.5	4.63	.50/.06	.50/.12	1.0	2.0
07-20-81	32.5	1.17	4.75	15.0	.25/.06	.54/.41*	2.16	6.83
09-15-81	33.75	2.56	17.75	6.46	.14/.04	.54/.38	3.86	9.5
12-01-81	22.0	1.25	10.75	4.33	.12/.03	.40/.21	3.33	7.0
04-03-82	12.25	1.61	6.0	2.53	.27/.07	.86/.33	3.19	4.7

* Occurred at end of storm event.

+ For period of actual precipitation only.

3.2.5 Analysis of Data

3.2.5.1. Relationship of Runoff to Precipitation. Data of storm event total precipitation, volume of runoff measured at the study site influent sampling point, and calculated runoff coefficients are presented in Table 3-12. Runoff coefficient values were calculated based on two different sized drainage areas: 299 acres and 749 acres. As explained previously, the size of the actual contributing area varies depending upon the size of the storm event. For storm events producing low intensity rainfall the actual drainage area would be expected to be close to 299 acres; for large storms with high intensity rainfall the assumed contributing drainage area would be somewhere between the two.

For the smaller drainage area the average of the mean runoff coefficients for the eleven events analyzed is 0.320, with a range of values of 0.151 to 0.525. For the larger area the average of the mean runoff coefficients is 0.128, with a range of 0.080 to 0.21.

The variability in the extent of the contributing drainage area precludes the determination of an accurate estimate of the runoff coefficient for the area tributary to Unqua Pond. The mean values of 0.320 and 0.128 can be considered as representative of the extremes in the range of values for possible contributing drainage areas, i.e., 299 to 749 acres. The "correct" runoff coefficient value lies somewhere between the two calculated mean values. The average of these two mean values is 0.224, which is close to the mean runoff coefficient value of 0.236 for the Deer Park study site where topography, land use and percent of impervious surface are very similar to those of the Massapequa site.

Table 3-12

UNQUA POND, MASSAPEQUA
STORM EVENT RUNOFF COEFFICIENTS

Date	Rainfall (inches)	Measured Runoff Volume (cubic feet)	299 Acre Drainage Area Runoff (inches)	299 Acre Drainage Area Runoff Coefficient	749 Acre Drainage Area Runoff (inches)	749 Acre Drainage Area Runoff Coefficient
09-18-80	0.54	117,450	0.108	0.200	0.043	0.080
09-25-80	0.38	95,195	0.088	0.232	0.035	0.092
11-03-80	0.43	70,955	0.065	0.151	0.026	0.060
10-25-80	1.30	488,840	0.450	0.346	0.180	0.138
11-17-80	0.45	142,550	0.131	0.291	0.052	0.116
02-02-81	0.58	252,110	0.232	0.400	0.093	0.160
07-01-81	0.25	96,120	0.089	0.356	0.035	0.140
07-20-81	1.17	487,900	0.449	0.384	0.179	0.153
09-15-81	2.56	1,460,100	1.345	0.525	0.537	0.210
12-01-81	1.25	502,440	0.463	0.370	0.185	0.148
04-03-82	1.61	471,575	0.434	0.270	0.173	0.107
		Mean		0.320		0.128

3.2.5.2. Bacteriological Parameters. Table 3-13 presents the ratios of fecal coliform to total coliform (FC/TC) and fecal coliform to fecal streptococci (FC/FS). The FC/TC ratio indicates the fraction of the coliform organisms that is considered to be of fecal origin. Ratios are given for stormwater runoff entering the impoundment (Influent) and for treated stormwater after passage through the impoundment (Effluent).

The observed range of values for the influent varied from a high of 47 percent to a low of 0.7 percent, with a mean value of 18 percent. Therefore, on the average, approximately one fifth of the coliform load in the runoff from this study site drainage area is attributable to fecal sources. The observed range of values for the effluent varied from a high of 73 percent to a low of 4 percent, with a mean value of 37 percent, which is double that of the influent.

The data indicate that the percentage of fecal coliform bacteria in the coliform load increases with the passage of runoff through the impoundment. There are several possible explanations for the increases in fecal coliform percentages observed in nine of the eleven events listed in Table 3-13. These include selective physical removal mechanisms operative within the impoundment, differing die-off rates for the multitude of coliform species, and the direct introduction of additional fecal coliform bacteria (or higher percentages of fecal coliforms in an additional coliform load) into the impoundment from an unknown source.

Table 3-13

UNQUA POND STUDY SITE

FECAL COLIFORM LOAD/TOTAL COLIFORM LOAD
FECAL COLIFORM LOAD/FECAL STREPTOCOCCAL LOAD

Date	Fecal Coliform/Total Coliform		Fecal Coliform/Fecal Strep	
	Influent	Effluent	Influent	Effluent
9-18-80	.15	.37	.86	.55
9-25-80	.25	.64	.65	.86
10-03-80	.47	.73	.56	1.94
10-25-80	.07	.34	.62	.46
11-17-80	.20	.38	.40	.66
02-02-81	.04	.04	.02	.03
07-01-81	.18	.14	.10	.77
07-21-81	.21	.27	.35	.62
09-17-81	.05	.22	.06	.89
02-01-82	.37	.46	.14	.50
04-03-82	.007	.45	.002	.20
Median	.18	.37	.35	.62
Mean	.18	.37	.34	.72

It is improbable that sedimentation would selectively remove more non-fecal than fecal coliform bacteria as runoff passes through the impoundment. Different survival rates for fecal and non-fecal coliforms could account for the observed increases in the percentage of the former following passage through the pond. However, work done by Geldreich (1968) indicates that non-fecal coliform bacteria, as exemplified by *Enterobacter aerogenes*, generally exhibit greater survival rates than do fecal coliform bacteria. The same has been shown to be true for fecal streptococci *(Streptococcus faecalis)* which generally have greater survival rates than fecal coliforms (Geldreich, 1968; Granai, 1981). Warmer temperatures tend to decrease survival time for all the species studied, with the greatest decrease noted for fecal coliforms. A decrease in the percentage of fecal coliforms in the pond effluent coliform load when compared to that in the influent, would have been expected, if survival or die-off rates were the only factors involved.

Based upon the data collected during the project, the reason for the observed changes appears to be the introduction of fecal coliforms in significantly greater numbers than non-fecal coliforms and fecal streptococci from an additional source downstream of the influent sampling location. The probable source of the additional bacterial load is examined in the discussion on control measure effectiveness.

Ratios of fecal coliform to fecal streptococci (FC/FS) are presented in Table 3-13. FC/FS ratios for the runoff influent to the impoundment for the eleven storm events ranged from 0.86 to 0.002, with a mean value of 0.35. Ratios for the impoundment effluent ranged from 1.94 to 0.03, with a mean value of 0.72. The significance, if any, of the changes in corresponding influent and effluent FC/FS ratios is not readily apparent. The effluent ratio was higher than the influent ratio during eight of the eleven events surveyed and lower during two events. There was no appreciable change in ratio during the remaining event, a winter storm.

FC/FS ratios must be interpreted with caution. Environmental factors, nutrient availability, and pollutant concentrations can influence the survival rate of each of the numerous species of bacteria that comprise the indicator groups. Consequently, the relative concentrations of the two groups of organisms can be expected to change. In addition, an introduction of bacteria from sources other than those contributing to the observed influent load could significantly alter the ratios in the runoff exiting from the impoundment.

FC/FS ratios for influent and effluent are all less than 1.0, with the exception of the pond effluent during one event. Furthermore, in most instances the ratios remained less than 0.7. Ratios of less than 0.7 indicate that the source or sources of the fecal bacteria are non-human warm-blooded animals.

3.2.5.3. Chemical Parameters. Storm load results for several of the inorganic chemical and physical pollutant parameters evaluated in the runoff are presented in Table 3-14. The indicated values were calculated based upon a contributing drainage area of 299 acres. Since the size of the contributing

drainage area for this study site varied depending upon the magnitude of the storm, the load factors listed in Table 3-14 are maximum values, and the load factors for larger storms are probably less than those indicated. The uncertainty of the contributing drainage area makes a more accurate determination impossible.

Runoff load factors for Total Suspended Solids ranged from 14.4 to 1.7

Table 3-14

UNQUA POND, MASSAPEQUA
SELECTED CHEMICAL PARAMETERS

Date	Rainfall (inches)	Wetfall (lbs/acre)	Runoff EMC (mg/l)	Unit Load (lbs/acre)	Load Factor (lbs/acre/in)
Parameter: Nitrate—as N					
09-18-80	0.54	0.025	2.04	0.052	0.096
09-25-80	0.38	0.052	2.69	0.075	0.197
10-03-80	0.43	0.035	1.97	0.040	0.093
10-25-80	1.30	0.047	0.74	0.084	0.065
11-17-80	0.45	0.019	1.15	0.040	0.089
02-02-81	0.58	0.017	1.09	0.092	0.159
07-01-81	0.25	0.013	0.77	0.019	0.076
07-20-81	1.17	0.217	1.23	0.160	0.640
09-15-81	2.56	0.064	0.74	0.225	0.088
Parameter: Nitrite—as N					
09-18-80	0.54	0.0006	0.0609	0.0015	0.0028
09-25-80	0.38	0.0005	0.0617	0.0017	0.0045
10-08-80	0.43	0.0005	0.0435	0.0009	0.0021
10-25-80	1.30	0.0012	0.0215	0.0024	0.0018
11-17-80	0.45	0.0007	0.0926	0.0032	0.0071
02-02-81	0.58	0.0012	0.0382	0.0032	0.0055
07-01-81	0.25	0.0002	0.0755	0.0019	0.0076
07-20-81	1.17	0.0005	0.0518	0.0068	0.0058
09-15-81	2.56	0.0012	—	—	—
Parameter: Ammonia—as N					
09-18-80	0.54	0.0086	0.388	0.010	0.019
09-25-80	0.38	0.0293	0.467	0.013	0.034
10-03-80	0.43	0.0058	0.350	0.007	0.016
10-25-80	1.30	0.0088	0.268	0.030	0.023
11-17-80	0.45	0.0092	0.554	0.019	0.042
02-02-81	0.58	0.0066	1.78	0.150	0.259
07-01-81	0.25	0.0023	0.171	0.004	0.016
07-20-81	1.17	0.1643	0.255	0.033	0.028
09-15-81	2.56	0.0262	—	—	—

Date	Rainfall (inches)	Wetfall (lbs/acre)	Runoff EMC (mg/l)	Unit Load (lbs/acre)	Load Factor (lbs/acre/in)
Parameter: Total Suspended Solids					
09-18-80	0.54	0.245	36.7	0.932	1.726
09-25-80	0.38	2.324	51.0	1.428	3.758
10-03-80	0.43	7.498	59.3	1.194	2.777
10-25-80	1.30	0.883	68.4	7.677	5.905
11-17-80	0.45	0.306	24.2	0.848	1.884
02-02-81	0.58	0.657	98.9	8.327	14.357
07-01-81	0.25	0.170	58.4	1.466	5.864
07-20-81	1.17	0.530	111.0	14.566	12.450
09-15-81	2.56	1.160	29.98	9.134	3.568
Parameter: Total Kjeldahl Nitrogen—as N					
09-18-80	0.54	0.053	1.26	0.032	0.059
09-25-80	0.38	0.063	1.28	0.036	0.095
10-03-80	0.43	0.010	0.84	0.019	0.044
10-25-80	1.30	0.041	1.38	0.155	0.119
11-17-80	0.45	0.034	1.22	0.043	0.096
02-02-81	0.58	< 0.013	1.99	0.168	0.290
07-01-81	0.25	0.014	1.56	0.039	0.156
07-20-81	1.17	0.292	1.68	0.220	0.188
09-15-81	2.56	< 0.025	0.856	0.261	0.102
Parameter: Total Phosphate—as P					
09-18-80	0.54	0.014	0.083	0.002	0.004
09-25-80	0.38	0.016	0.182	0.005	0.013
10-03-80	0.43	0.001	0.085	0.002	0.005
10-25-80	1.30	0.014	0.274	0.031	0.024
11-17-80	0.45	0.003	0.272	0.010	0.022
02-02-81	0.58	0.004	0.374	0.032	0.055
07-01-81	0.25	0.0001	0.215	0.005	0.020
07-20-81	1.17	0.006	0.278	0.036	0.031
09-15-81	2.56	0.010	0.153	0.047	0.018

pounds per acre per inch of rain. These values, while lower than those calculated for the Bayville study site, are similar to those obtained at the other South Shore study site, Central Avenue, Deer Park, which is topographically similar.

The range of values for each of the five listed inorganic chemical parameters, total Kjeldahl nitrogen, ammonia nitrogen, nitrite and nitrate nitrogen, and total phosphate, are very similar to those calculated for Central Avenue. Determinations of seasonal variations in loading factors are generally not possible because most of the storm events surveyed at the Unqua Pond study site occurred during the warmer summer and early fall months. The one winter event surveyed occurred during an unusual February thaw. Load factors for total suspended solids, total Kjeldahl nitrogen, ammonia and total phosphate calculated for the February event are the highest values among those listed for the nine events sampled. The high total Kjeldahl nitrogen loading reflects the high ammonia component, which comprises 90 percent of the total Kjeldahl loading.

These elevated values may indicate possible seasonal variations for winter storm events. Higher values during this event are not attributable to high rainfall volume or intensity, since the total rainfall was 0.58 inch, and hourly and fifteen-minute intensities were quite uniform over the five and one-half hours of precipitation. The average intensity rate was 0.11 inch per hour, whereas the observed maximum was 0.13 inch per hour. Increased loading may be attributable to residues left on the landscape when previously accumulated ice and snow melted prior to the occurrence of this storm event.

3.2.6. CONTROL MEASURE EVALUATION

3.2.6.1. Load Reduction Analysis. Tables 3-15, 3-16, and 3-17 illustrate the removal efficiencies for total and fecal coliform bacteria, as well as for fecal streptococci, for the eleven storm events surveyed. The bacteriological loads are expressed as most probable numbers (MPN) of organisms. Both the influent and effluent loads were determined by multiplying the calculated event mean concentration (EMC) by the volume of flow measured during the sampling interval. The percent reductions are expressed in two ways. The first, the uncorrected reduction, was based upon the loads associated with flow volumes measured during the time of sampling only. The second, the corrected percent reduction, was calculated based upon an assumed linear extrapolation of load when influent and effluent volumes are equalized. However, in contrast to the approach taken by the project consultant (see Appendix D, LMS Report, Page 5.0-18), which considered only pond influent and effluent measured flows, additional assumed flow and loading were assigned to those

Table 3-15

UNQUA POND INFLUENT AND EFFLUENT BACTERIOLOGICAL LOADS
PERCENT REDUCTION—TOTAL COLIFORM

Date	Rain Volume (inches)	Duration Rain/Runoff[a] (hours)	Load (MPN) Influent[b]	Load (MPN) Effluent[b]	Percent Reduction[b] (Uncorrected)	Percent Load Passing Through Pond[d]	Load (MPN) Influent[c]	Load (MPN) Effluent[c]	Percent Reduction[c] (Corrected)
09-18-80	0.54	5.5/4.2	5.17×10^{12}	0.17×10^{11}	99.7	30	5.89×10^{12}	5.67×10^{10}	99.0
09-25-80	0.38	16.5/4.8	4.85×10^{12}	0.19×10^{11}	99.6	28	5.53×10^{12}	6.79×10^{10}	98.8
10-03-80	0.43	6.5/7.5	1.07×10^{12}	0.29×10^{11}	97.3	48	1.22×10^{12}	6.04×10^{10}	95.0
10-25-80	1.30	9.3/14.3	4.98×10^{12}	1.71×10^{12}	65.7	54	5.68×10^{12}	3.17×10^{12}	44.2
11-17-80	0.45	6.8/9.2	1.57×10^{12}	0.37×10^{11}	97.6	25	1.79×10^{12}	1.48×10^{11}	91.7
02-02-81	0.58	6.5/11.8	1.05×10^{12}	0.45×10^{11}	95.7	50	1.20×10^{12}	9.0×10^{10}	92.5
07-01-81	0.25	1.06/6.4	1.22×10^{12}	0.93×10^{11}	92.4	37	1.39×10^{12}	2.51×10^{11}	81.9
07-20-81	1.17	32.5/35.8	23.9×10^{12}	0.76×10^{12}	96.8	56	27.3×10^{12}	1.36×10^{12}	95.0
09-15-81	2.56	33.8/36.0	19.7×10^{12}	10.4×10^{12}	47.2	58	22.5×10^{12}	17.9×10^{12}	20.3
Dye Studies									
12-01-81	1.25	22.0/24.0	1.91×10^{12}	6.63×10^{11}	65.3	70	2.18×10^{12}	9.47×10^{11}	56.6
04-03-82	1.61	12.2/17.0	0.96×10^{12}	5.26×10^{11}	45.7	102	1.12×10^{12}	5.26×10^{11}	53.0

[a] At influent.

[b] Based on influent and effluent volumes measured during the time of sampling only

[c] Based upon equal influent and effluent volumes and loads to pond not measured at influent.

[d] Percent load passing through pond $= \frac{\text{Volume of effluent measured during sampling}}{\text{Total volume of stormwater that entered pond}} \times 100$

Table 3-16

UNQUA POND INFLUENT AND EFFLUENT LOADS, PERCENT REDUCTION—FECAL COLIFORM

Date	Rain Volume (inches)	Duration Rain/Runoff[a] (hours)	Load (MPN) Influent[b]	Load (MPN) Effluent[b]	Percent Reduction[b] (Uncorrected)	Percent Load Passing Through Pond[d]	Load (MPN) Influent[c]	Load (MPN) Effluent[c]	Percent Reduction[c] (Corrected)
09-18-80	0.54	5.5/4.2	7.93×10^{11}	6.31×10^{9}	99.2	30	9.04×10^{11}	2.10×10^{10}	97.7
09-25-80	0.38	16.5/4.8	1.21×10^{12}	1.22×10^{10}	98.9	28	1.38×10^{12}	4.36×10^{10}	96.8
10-03-80	0.43	6.5/7.5	5.07×10^{11}	2.13×10^{10}	95.8	48	5.78×10^{11}	4.44×10^{10}	92.3
10-25-80	1.30	9.3/14.3	3.68×10^{11}	5.75×10^{11}	56% increase	54	4.20×10^{11}	10.65×10^{11}	154% increase
11-17-80	0.45	6.8/9.2	3.14×10^{11}	1.42×10^{10}	95.5	25	3.58×10^{11}	5.68×10^{10}	84.1
02-02-81	0.58	6.5/11.8	4.07×10^{10}	1.71×10^{9}	95.8	50	4.64×10^{10}	3.42×10^{9}	92.6
07-01-81	0.25	1.0/6.4	2.16×10^{11}	1.27×10^{10}	94.1	37	2.46×10^{11}	3.43×10^{10}	86.1
07-20-81	1.17	32.5/35.8	4.97×10^{12}	2.05×10^{11}	95.9	56	5.67×10^{12}	3.66×10^{11}	93.5
09-15-81	2.56	33.8/36.0	9.26×10^{11}	2.25×10^{12}	143% increase	58	1.06×10^{12}	3.88×10^{12}	266% increase
Dye Studies									
12-01-81	1.25	22.0/24.0	7.09×10^{11}	3.06×10^{11}	56.8	70	8.08×10^{11}	4.37×10^{11}	45.9
04-03-82	1.61	12.2/17.0	6.39×10^{9}	2.36×10^{11}	3690% increase	102	7.43×10^{9}	2.36×10^{11}	3176% increase

Table 3-17

UNQUA POND INFLUENT AND EFFLUENT BACTERIOLOGICAL LOADS, PERCENT REDUCTION—FECAL STREPTOCOCCI

Date	Rain Volume (inches)	Duration Rain/Runoff[a] (hours)	Load (MPN) Influent[b]	Load (MPN) Effluent[b]	Percent Reduction[b] (Uncorrected)	Percent Load Passing Through Pond[d]	Load (MPN) Influent[c]	Load (MPN) Effluent[c]	Percent Reduction[c] (Corrected)
09-18-80	0.54	5.5/4.2	9.21×10^{11}	1.15×10^{10}	98.8	30	1.05×10^{12}	3.83×10^{10}	96.4
09-25-80	0.38	16.5/4.8	1.87×10^{12}	1.42×10^{10}	99.2	28	2.13×10^{12}	5.07×10^{10}	97.6
10-03-80	0.43	6.5/7.5	9.02×10^{11}	1.10×10^{10}	98.8	48	1.03×10^{12}	2.29×10^{10}	97.8
10-25-80	1.30	9.3/14.3	5.92×10^{12}	1.25×10^{12}	78.9	54	6.75×10^{12}	2.32×10^{12}	65.6
11-17-80	0.45	6.8/9.2	7.78×10^{11}	2.14×10^{10}	97.2	25	8.87×10^{11}	8.56×10^{10}	90.3
02-02-81	0.58	6.5/11.8	2.41×10^{12}	5.17×10^{10}	97.9	50	2.75×10^{12}	1.03×10^{11}	96.3
07-01-81	0.25	1.06/6.4	2.25×10^{12}	1.64×10^{10}	99.3	37	2.57×10^{12}	4.43×10^{10}	98.3
07-20-81	1.17	32.5/35.8	1.44×10^{13}	3.31×10^{11}	97.7	56	16.4×10^{12}	5.91×10^{11}	96.4
09-15-81	2.56	33.8/36.0	1.48×10^{13}	2.53×10^{12}	82.9	58	16.9×10^{12}	4.36×10^{12}	74.2
Dye Studies									
12-01-81	1.25	22.0/24.0	5.03×10^{12}	6.06×10^{11}	88.0	70	5.73×10^{12}	8.66×10^{11}	84.9
04-03-82	1.61	12.2/17.0	2.69×10^{12}	1.19×10^{12}	55.8	102	3.07×10^{12}	1.19×10^{12}	61.2

[a] At influent.

[b] Based on influent and effluent volumes measured during the time of sampling only

[c] Based upon equal influent and effluent volumes and loads to pond not measured at influent.

[d] Percent load passing through pond $= \frac{\text{Volume of effluent measured during sampling}}{\text{Total volume of stormwater that entered pond}} \times 100$

areas located downstream of the influent sampling location and draining directly to the pond. Based upon the extent and assumed imperviousness of these areas, the total additional runoff flow and load entering the pond was estimated to be 14 percent of that measured at the influent to the pond.

Table 3-15 reveals that, for six of the eleven storm events, uncorrected total coliform removal efficiencies were in excess of 95 percent, while corrected values ranged from 92 to 99 percent. Total rainfall per event ranged from 0.38 to 1.17 inches, with an average of 0.6 inch. Rainfall duration per event varied from 5.5 to 32.4 hours, with an average of 12.4 hours. For the remaining five events, uncorrected removal efficiencies varied from 46 to 92 percent, while corrected values ranged from 20 to 82 percent. Total rainfall varied from 0.25 to 2.56 inches, averaging 1.39 inches, while event duration varied from 1.0 to 33.8 hours and averaged 15.6 hours.

Tables 3-16 and 3-17 present load reduction data for fecal coliform and fecal streptococcal bacterial loads evaluated during the eleven surveyed events. Uncorrected percent reductions for fecal coliforms ranged from 99 to 57 percent, while corrected values ranged from 98 to 46 percent. For three events, the effluent load of fecal coliform bacteria exceeded the influent load. The range of uncorrected removals observed for fecal streptococci went from a high of 99 percent to a low of 56 percent. Correcting the loads to account for the assumed unmeasured load draining directly to the pond changes the range of reductions to 98 to 61 percent.

A review of the rainfall patterns of the eleven surveyed storm events indicates that there were periods of intense rainfall during the five storm events for which reduced bacteriological removal efficiencies within the pond were observed. Four of the five storms had high total rainfall volumes ranging from 1.25 to 2.56 inches while the fifth storm produced only 0.25 inch of rain. However, during all five storms, recorded hourly maximum intensities were 0.40 inch or greater. In the case of the storm events for which the associated pond reduction efficiencies were high, periods of intense precipitation (i.e. greater than 0.30 inch per hour) either did not occur or were of short duration (15 minutes or less), with one exception. During the storm of July 20, 1980, the high intensity rainfall occurred at the very end of the precipitation period. Periods of prolonged high intensity precipitation caused the rapid introduction of large volumes of high-velocity runoff, apparently disrupting the removal mechanisms operating in the impoundment (e.g., it interferes with the sedimentation of suspended particles).

Retention of runoff volume within impoundments over a period of time sufficient to allow for settling of suspended particles, with their adsorbed pollutants, and bacterial die-off or other mechanisms of bacterial density reduction were viewed as the most likely mechanisms for producing the attenuation of the indicator bacterial loading prior to the discharge of runoff to the receiving waters. It was suspected that short circuiting of runoff flow through impoundments occurs under certain storm conditions and results in decreased bacterial reductions. In order to demonstrate that short circuiting does occur, and to determine its extent, two dye studies were conducted on Unqua Pond. In order to clearly demonstrate the existence of short circuiting, the dye studies had to be conducted during storm events of sufficient magnitude (prolonged high intensity and/or sufficient total precipitation) to produce runoff volumes capable of generating short circuiting within the pond.

Dye studies were conducted on December 1, 1981 and April 3, 1982. On both occasions, Uranine dye (sodium fluorescein) was introduced into the pond influent stream at the beginning of the storm event when influent flow had increased at least ten percent above baseflow. One pound of Uranine dye, of which 88 percent is fluorescein (.883 lbs.), was utilized during the first study; two pounds (1.766 lbs. fluorescein), during the second. Uranine was selected because of its low affinity for adsorbing on the surface of suspended paricles, high solubility in water, non-toxicity to fauna and flora at high concentrations, insensitivity to temperature changes and detectability at extremely low concentrations via fluorometric analysis (detection limit 1 μg/l). Two disadvantages were not deemed to pose a problem: increasing sensitivity to pH values below 5.5 and the dye's very high photochemical decay rate. Intensive sampling was conducted at the pond effluent spillway. Dye concentrations in pond effluent samples were determined utilizing a Turner Model 111 Fluorometer. Concentration curves were developed using laboratory prepared standards.

Meteorological conditions for the two dye-study storm events were as follows:

	12/1/81	4/3/82
Total Precipitation (inches)	1.24	1.61
Hourly Rainfall Intensity:		
Average (inches/hour)	0.12	0.27
Maximum (inches/hour)	0.40	0.86
Wind Velocity (mph)	5-10	30 +
Direction	Westerly	Southerly

In both studies, the first traces of dye arrived at the pond effluent prior to the major portion of the runoff. For the December event there was a lag time of 8.5 hours between dye introduction and the first appearance of dye at the effluent point, with a total precipitation accumulation of 0.52 inch during this time period. For the April event there was a lag time of 5 hours, with a total precipitation accumulation of 0.29 inch at the time of dye detection in the effluent water stream.

Visual observation of dye travel through the impoundment was possible during the April test. A well-defined stream of runoff, with a high concentration of dye, was observed to travel rapidly toward the effluent end of the pond, close to and parallel with the eastern shoreline. The dye stream approached to within 75 feet of the effluent spillway and proceeded upstream along the western side of the pond, still in a well-defined band. Dye was first observed in the pond effluent approximately two hours after the time when the dye stream

had approached the effluent end of the pond, which was three hours after dye introduction. It was concluded that the strong southerly wind during this dye study had produced a clockwise gyre within the pond, which resulted in the runoff flow moving rapidly as a confined stream toward the effluent end of the impoundment. Wind conditions, especially during storm events with low intensity rainfall, may be a determining factor in producing hydraulic short circuiting within impoundments because of induced internal circulation. The more circular the shape of the impoundment, the greater the tendency toward swirling.

From the results of these two dye studies, it can be inferred that similar hydraulic short circuiting occurred, to a greater or lesser degree, during the remaining nine storm events evaluated, including those events where bacterial reductions were one order of magnitude or more.

The project consultant evaluated the data for the December dye test. (See Appendix D.) This analysis estimated the degree of short circuiting during this particular storm event at approximately 40 percent. Bacterial load reductions (uncorrected) for this event were calculated to be 65 percent for total coliform bacteria, 56 percent for fecal coliform bacteria, and 88 percent for fecal streptococcal bacteria. Corrected values for the three bacteriological indicator groups lowered the respective load reductions to 57, 46, and 85 percent.

The results of the second dye study were analyzed by the Nassau County Department of Health using the consultant's methodology, found that of the 1.766 pounds of fluorescein introduced, only one-third could be accounted for. No adequate explanation can be offered for the apparent loss or disappearance of two-thirds of the dye. The loss cannot be attributed to low pH effects since the pH of the influent water (runoff) was nearly neutral (7.0) and the pond water was slightly alkaline. Photochemical decomposition is not considered to be significant since the test was conducted in part under conditions of heavy cloud cover and primarily during night-time hours. Some dye loss may be attributable to chemical reactions with one or more of the pollutants contained in the runoff.

Twenty hours after the introduction of the dye, and ten hours after cessation of the rainfall, the pond still contained almost one-half of the initial dye [value corrected to account for dye loss, calculated loss coefficient $K_{10} = 0.55$ day^{-1} (base 10)]. At this point a greater volume of water was recorded as having exited from the pond than had entered at the influent. This observation is not contradictory since drainage from the adjacent park (primarily the impervious parking lot), as well as the residential area in the southwest corner of the drainage area, enters below the main influent point.

If the pond is assumed to contain one-half of the introduced dye, the other half is assumed to have exited the pond by the end of sampling. Dividing the total effluent volume at the time of sample cessation by the pond volume gives the effectivenes of pond retention. For this particular dye study, the retention effectiveness was 70 percent, which is equivalent to short circuiting of 30 percent. Results for the two dye studies indicate that hydraulic short circuiting within the impoundment can be expected to occur to a greater or lesser degree during the majority of storm events, and that the amount of rainfall needed to initiate and sustain short circuiting need not be extensive. Wind direction and velocity during a storm event can intensify short circuiting by producing swirling within the impoundment. Corresponding bacterial reduction percentages (corrected values) for the April 1982 event were 53 for the total coliform bacterial load and 61 for fecal streptococcal bacterial load. What was found to be most significant was the dramatic increase in the fecal coliform load detected in the effluent (Table 3-16). The amount of fecal coliform bacteria exiting the impoundment was over thirty-six times greater than the total amount detected in the influent runoff (as measured at the influent sampling point). The probable explanation for such a significant increase is that an even greater load was being introduced by runoff entering directly into the pond from the adjacent park area than that which was assumed in the calculations for correcting the loads. Similar increases in the fecal coliform load exiting the pond were observed during two additional storm events (Table 3-16). During these two events, increases in fecal coliform load, over that which was introduced via the influent stream, amounted to 154 percent and 266 percent (corrected values). The source of this additional fecal coliform bacterial load measured in the pond effluent is likewise believed to be the fecal wastes deposited by waterfowl on the adjacent park property and subsequently washed into the pond.

3.2.6.2. Waterfowl Impact Upon Pond Water Quality. As part of the Long Island NURP study, an investigation was conducted by the Nassau County Department of Health to determine the effect of waterfowl activities on pond water quality (see Appendix E). Over a ten-month period extending from November 1979 to August 1980, three ponds were sampled for influent and effluent total and fecal coliform, fecal streptococci and nitrogen. The three sites were chosen primarily to represent a range of waterfowl densities. Thus, Massapequa Reservoir (16 acres) has 1.6 waterfowl per acre, Unqua Pond (5.5 acres) has 17 per acre and Tackapausha (Seaford) Pond (1.7 acres) has 224 per acre.

The samples were collected during both wet and dry days and the results are presented for each. A dry day was defined as one in which a rainfall event did not occur on the sampling day or within 72 hours prior to that day. A wet day was defined as one in which a rainfall event of at least 0.1 inch of rain occurred, or one in which such a rainfall had occurred no more than 72 hours previously.

Review of the data suggests that water-related impacts upon the bacteriological quality of the pond are greatest at Tackapausha. In the case of Unqua Pond, waterfowl were suspected to be at least partially responsible for

the water-quality degradation. The waterfowl at Massapequa Reservoir were determined to have little or no effect on reservoir water quality.

Although it might appear that the elevated average effluent concentrations for samples collected during wet days at Unqua are at variance with those for samples collected during the eleven stormwater runoff surveys, this is not believed to be the case. During dry weather, waterfowl are believed to be the main cause of the elevated total and fecal coliform effluent levels in both Tackapausha and Unqua Ponds. This is based upon the fact that there are no drains entering Tackapausha, and that two of the three drains entering Unqua (storm drains from the parking lot) were observed to be dry at all times during dry weather periods. The third drain, not readily accessible, is the outlet for a storm sewer system draining a few acres of residential development. However, the likelihood of illegal residential sanitary sewage discharges via this drain is remote since the surrounding area has been sewered for a number of years, and only two residences (single family) within the drainage area remain unconnected to the sanitary sewer. Therefore, since during dry weather a major portion of bacteria originates from a source other than the influent, the removal efficiency of the pond cannot be readily determined, as it can during storm flows, by taking the difference between the average influent and effluent values and dividing by the average influent value.

A question still remains as to why the wet weather effluent average bacteriological concentrations for both total and fecal coliform and fecal streptococci at Unqua and Tackapausha were significantly greater than those found in the wet weather influent during the waterfowl study. This appears to contradict the findings that, during the majority of the storm events monitored as part of the NURP study, the pond removed more than 90 percent of the total coliform bacteria measured in the pond influent.

In order to attempt to answer this question, it should be recalled that a "wet" sample was one taken anytime during a period of 72 hours after a rainfall event of at least 0.1 inch. While samples designated as "wet" no doubt included some taken during or immediately after a rainfall event, it is most likely that the majority of "wet" samples were taken within a period of from 24 to 72 hours following such an event. Experience has shown that, for the Unqua Pond, influent waterstream bacterial concentrations decrease rapidly as flow returns to baseline conditions. Therefore, a number of the samples classified as "wet" more realistically reflect "dry" conditions. In this case, the elevated effluent concentrations may be, at least in part, attributed to waterfowl; the degree to which this is true depends upon the characteristics of the preceding storm event.

Unqua Pond and the adjacent park have a significant resident water fowl population of about one hundred birds, sustained primarily by public feeding. Both the pervious and impervious surfaces are extensively covered with fecal material deposited by waterfowl (e.g., Mallards, Canada geese, and gulls). Wastes deposited on the impervious parking lot contribute a bacterial load during most storm events, since this area drains directly into the pond. Previous areas have been observed to accumulate rainwater in depressions during storm events and to intermittently contribute runoff to the impoundment when rainfall is of sufficient intensity and/or duration. The land elevation immediately adjacent to the impoundment where the waterfowl congregate ranges from six inches to two feet above the dry weather surface elevation of the impoundment.

An attempt was made to estimate the potential fecal coliform loading that could be introduced directly into the impoundment from the avian fecal wastes deposited on the parkland adjacent to Unqua Pond. Given the daily per capita production of fecal matter and the estimated fecal coliform MPN per gram of fecal matter for the implicated species, the daily load available for washoff can be calculated.

Ducks (species unidentified) produce about 335 grams of fecal material per day per individual, with each gram of waste containing approximately 33 million fecal coliform bacteria (Geldreich, 1966). Geese (species unidentified) produce about 1500 grams of fecal material per day per individual with each gram containing about 33 million fecal coliform bacteria (Lawler, Matusky and Skelly, 1982). Therefore, the total number of fecal coliform bacteria eliminated by the water fowl population at Unqua Pond was estimated to be approximately 3×10^{12} organisms per day.

During storm events, some percentage of this daily load will be carried off the land surface, from impervious areas at least, and into the impoundment. If ten percent of this daily load had entered the impoundment during each of the storm events surveyed, the resultant pond effluent loads attributable to waterfowl wastes, for the eleven storm events, would have exceeded that which was actually measured at the effluent sampling point during eight of the eleven storms. The three events during which the actual measured fecal coliform effluent load exceeded ten percent of the estimated additional waterfowl load are those events during which measurable increases in fecal coliform loads were observed (10/25/80; 9/15/81; 4/3/82). The assumption that more than ten percent of the waterfowl fecal coliform load available for washoff had entered the impoundment during these three events would account for the observed increases.

Even if only one percent of the bacteria available for washoff was actually carried into the impoundment, the resultant effluent loads would have exceeded that which was measured during six of the eleven storms. In actuality, the load of bacteria in the runoff from the parkland would be determined by numerous factors including bacterial survial rates, which are determined by environmental factors; rainfall intensities; storm volume and duration; and the cumulative number of bacteria deposited by the waterfowl.

The concentration of fecal streptococci in duck and goose fecal matter is greater than that of fecal coliforms [FC/FS ratio of 0.6 for ducks (Geldreich, 1966]. However, in the case of the three events during which significant increas in fecal coliforms were observed, no corresponding proportional increases were noted in fecal streptococcal concentrations. Rapid die-off of one

or more of the fecal streptococcal strains may have accounted for reduced fecal streptococcal densities available for washoff. *Streptococcus bovis* is known to have a disproportionately low survival rate outside of the intestinal tract of animals (EPA 1977). Even though increased fecal streptococcal effluent loads were not observed, the percent reductions from influent to effluent (Table 3-17), where considerably lower for these three events. These lower removals can be interpreted as indicating that more of the measured influent load had survived to reach the effluent sampling point and/or that an additional load, applied to the impoundment but not measured at the influent point, was detected in the effluent. Since the increased fecal coliform load could be best explained by the introduction of an additional load, it is reasonable to ascribe the lower fecal streptococcal removals to the same additional source, i.e., washoff of waterfowl fecal material.

Total coliform removals were also lower during the same three storm events that exhibited increases in fecal coliforms, (Table 3-15). Fecal coliform bacteria are a component of the total coliform group, so that their increased numbers during the three events were reflected in the total coliform concentrations. It is possible to obtain a better estimate of the removal efficiencies relating to the runoff entering through the main stream channel if removal efficiencies are calculated using the non-fecal component of the coliform group, determined by subtracting fecal coliform loads (Table 3-16) from the corresponding total coliform loads (Table 3-15). When only the non-fecal coliform bacteria are considered, the percent reductions for the three storm events exhibiting increased fecal coliform loads (10/25/80, 9/15/81, 4/3/82) are 75, 57, and 70. Correcting the loads to account for an assumed non-fecal coliform load draining directly into the pond and equalizing flow volumes changes the percent reductions to 60, 34, and 74, respectively.

Even though the performance of the pond in achieving reduction of bacterial loads appears better when the effects of the waterfowl load are discounted, the reductions for these larger storms still remain well below 90 percent.

The finding that an additional load of fecal coliform bacteria (and by implication additional fecal streptococcal loads) was introduced into the impoundment during three of the storm events surveyed, presumably from the adjacent parkland property, raises the question as to whether or not additional loads were introduced into the pond during most or all of the sampled storm events, and whether these additional loads were the primary sources of the measured effluent bacterial concentrations. The dye studies indicated that the water, which originated as runoff and was sampled as influent, constituted a major portion of the sampled pond effluent volume. The remainder of the sampled effluent then consisted of displaced pond water, together with any additional runoff to the impoundment from sources downstream of the influent sampling location. Analytical results of water samples taken prior to the onset of surveyed storm events indicate that bacterial concentrations of the pond effluent between storm events are generally one to two orders of magnitude less than the event mean concentrations for the corresponding indicator groups during the storm events. The logarithmic average bacterial concentrations in the effluent sampled before the storms were 196 MPN/100 ml for total coliforms, 64 MPN/100 ml for fecal coliforms, and 85 MPN/100 ml for total streptococci.

If additional loads of fecal bacteria are, in fact, introduced into the impoundment during most storm events, then the removal efficiency of the pond with respect to bacteria entering at the pond upstream influent is greater than the values indicated in Tables 3-15, 3-16, and 3-17.

3.2.6.3. Prediction of Bacteriological Reductions of Runoff in Ponds. Driscoll (Sept. 1982) (Dec. 1982) has adapted and further developed a screening technique for predicting the expected bacteriological reductions obtained by sedimentation basins under varying conditions of runoff flow and volume. Using the quotient of two factors, he was able to demonstrate what appears to be a relationship between this quotient and bacteriological removals within Unqua Pond.

The first of these factors, called a Volume Ratio, is defined as follows:

$$\text{Volume Ratio} = \frac{\text{Basin Volume}}{\text{Storm Runoff Volume}} = \frac{V_B}{V_R}$$

The Volume Ratio is a measure of the extent to which the pond volume is occupied by the runoff generated during the storm event. The larger the ratio, the better are the removals which can be expected to occur.

The second factor, which is really equal to the Surface Overflow Rate, is defined by the following equation:

$$\text{Surface Overflow Rate} = \frac{\text{Average Runoff Rate of Flow}}{\text{Pond Surface Area}} = \frac{\overline{QR}}{A}$$

The lower the values of the overflow rate, the better the removals that can be expected in the pond. This assumes that the pollutants being measured are associated with particulate matter whose removal is, to a significant degree, a function of the surface overflow rate.

The effects related to storage (Volume Ratio) were combined with those related to sedimentation (Surface Overflow Rate) by Driscoll in the form of a third factor, **f**, as follows:

$$f = \frac{\text{Volume Ratio}}{\text{Surface Overflow Rate}} = \frac{V_B/V_R}{\overline{QR}/A}$$

Higher values of **f** reflect better conditions for removal.

The results of Driscoll's analysis of the Unqua Pond findings are presented in Table 3-18 and Figures 3-8, 3-9, 3-10, and 3-11. When f was plotted against percent reduction using logarithmic coordinates, it was found that removals at Unqua Pond were generally greater than 90 percent for total and fecal coliform, fecal streptococcal and non-fecal coliform bacteria when f was greater than 20. Bacteriological removals were significantly less during larger storm events when f was less than approximately 20.

Table 3-18

UNQUA POND, MASSAPEQUA
f-FACTOR VERSUS BACTERIAL INDICATOR REDUCTION

Date of Storm Event	V_B/V_R[a]	$\overline{QR}/A$[b]	f[b]	Percent Reduction[d] Total Coliform	Fecal Coliform	Fecal Streptococci
09-15-81	0.47	0.19	2.4	20	(increase)	74
10-25-80	1.40	0.16	8.6	48	(increase)	68
04-03-82	1.46	0.13	11.0	53	(increase)	62
12-01-81	1.37	0.10	14.0	57	46	85
07-20-81	1.41	0.065	22.0	96	95	97
02-02-81	2.73	0.10	27.0	94	94	97
09-18-80	5.86	0.10	58.0	99	98	97
11-17-80	4.83	0.07	65.0	79	84	98
07-01-81	7.16	0.07	101.0	79	84	98
10-03-80	9.70	0.05	216.0	96	94	98
09-25-80	7.23	0.03	268.0	99	98	99

Note: Storm events listed in order of increasing f
(a) V_B = Pond volume, 785,000 cubic feet; V_R = Volume of storm runoff
(b) QR = Average runoff rate; A = Surface area of pond in square feet.
(c) $f = (V_B/V_R)/(\overline{QR}/A)$.
(d) percent reduction based on influent and effluent EMC's.

Driscoll's technique is very useful for a number of reasons. First, it permits the approximation of the expected bacteriological removal under a range of meterological conditions for a given pond. For example, assuming that the mean storm on Long Island consists of 0.43 inches of rainfall, and that the distribution of storms follows a gamma distribution, then 63 percent of all storms will be equal to or less than 0.43 inches. For the mean storm, the value of f would be equal to 44 for Unqua Pond. Referring to Figs. 3-8, 3-9, and 3-10, this f-value corresponds to removals of approximately 97, 96 and 97 percent for total and fecal coliform bacteria and fecal streptococci, respectively. The f-factor corresponding to the rainfall and runoff expected to be exceeded only once per year (99 percent storm) has an f value of approximately 6. Referring to Figs. 3-8 and 3-10 this is equivalent to total coliform and fecal streptococci

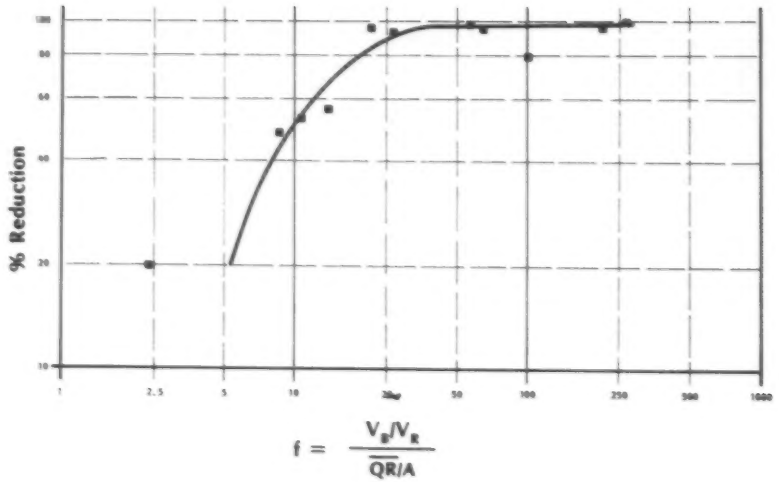


FIGURE 3-8 *Unqua Pond, Massapequa: Total coliform, percent reduction vs. f*

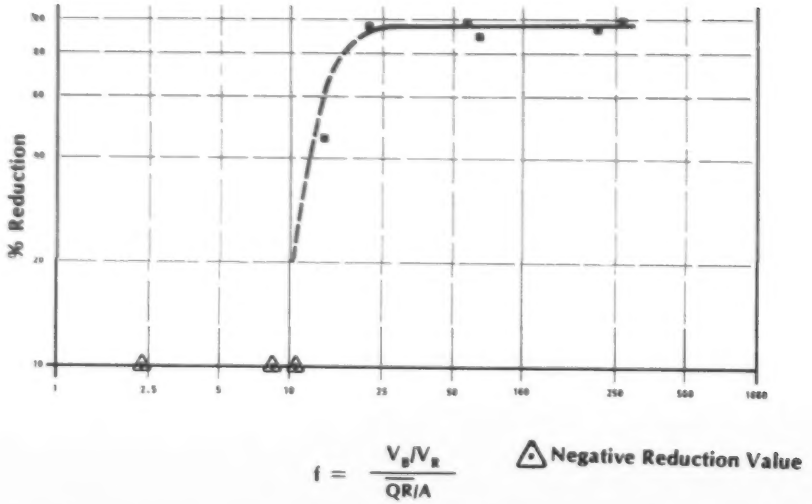


FIGURE 3-9 *Unqua Pond, Massapequa: Fecal coliform, percent reduction vs. f*

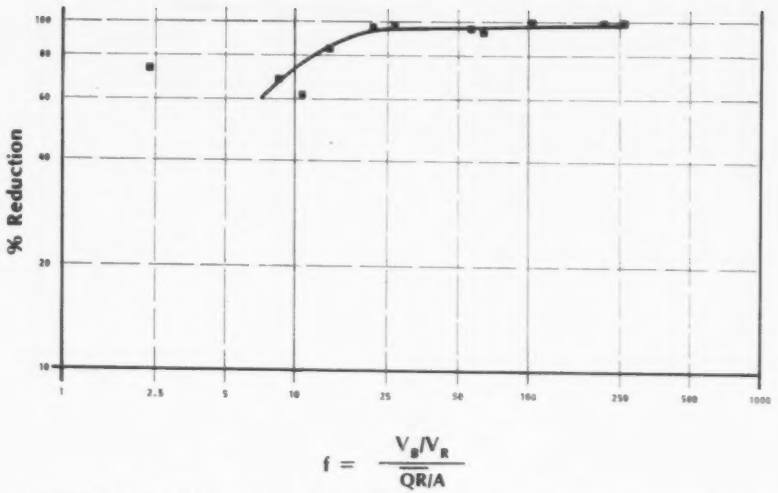


FIGURE 3-10 *Unqua Pond, Massapequa: Fecal streptococci, percent reduction vs. f*

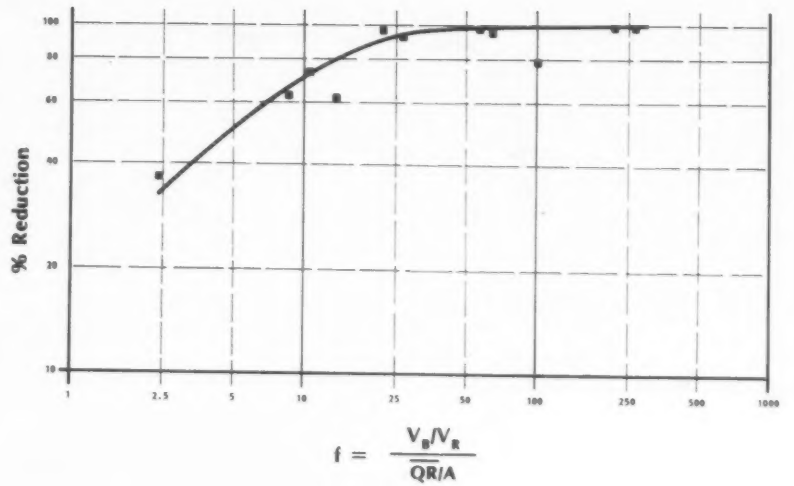


FIGURE 3-11 *Unqua Pond, Massapequa: Non-Fecal coliform, percent reduction vs. f*

removals of 25 and approximately 50 percent, respectively. For fecal coliform the results indicate that there are no removals but rather the addition of these bacteria at **f** values of approximately 10 or less. The probable explanation for this has already presented (Section 3.2.6.1).

In an attempt to obtain a more reliable evaluation of bacteriological removal by the pond, the percent removal of non-fecal coliform was plotted versus **f**. In this way, the effect of any additions of fecal coliforms directly to the pond would not be a factor in determining pond removal efficiencies. This assumes that the vast majority of any coliforms added directly to the pond is of fecal origin. Returing, for a moment, to the mean storm event, when **f** equals 44, it is seen from Fig. 3-11 that approximately 97 percent of the non-fecal coliforms are removed. This is identical to the predicted removals of the other measured bacterial species. For the 99 percent storm approximately 55 percent of the non-fecal coliforms are estimated to be removed.

This screening technique also makes it possible to determine the effects of varying pond volume upon expected removals. The utility of this technique thus becomes immediately obvious, provided that the predicted results compare satisfactorily with those measured at other impoundments as well.

3.3 CENTRAL AVENUE (CARLLS RIVER), DEER PARK, SITE

3.3.1 Site Description. The stormwater drainage system of this study site serves a portion of Deer Park in the Town of Babylon, which is in western Suffolk County (Fig. 3-12).

A primary reason for selecting this site was that the 73 acre drainage area had been developed for medium density residential use, by far the most prominent land use in this portion of the county. In the drainage area, all building lots were occupied and had generally been so for at least twenty years. The average lot size is 7,500 square feet, with more than 3,100 square feet of the lot covered by turf. Impervious surfaces account for approximately 20% of the total area.

A door-to-door survey in this area indicated that homeowners applied fertilizer to their lawns at an average rate of 2.69 pounds of nitrogen per 1,000 square feet of turf per year, which is consistent with the areawide average indicated in previous regional surveys conducted for the Long Island 208 study. The survey also indicated that approximately one-half of the households had a dog, which is also typical of most communities on Long Island. The significance of this dog population to the quality of stormwater runoff is discussed later in this report.

As shown on Fig. 3-12 the drainage system for this study site discharges to the west branch of the Carlls River, about one mile north of Belmont Lake. The Carlls River is the freshwater stream with the largest base flow that discharges into western Great South Bay. Another reason for selecting this site was that a substantial portion of this section of the bay is uncertified for shellfishing.

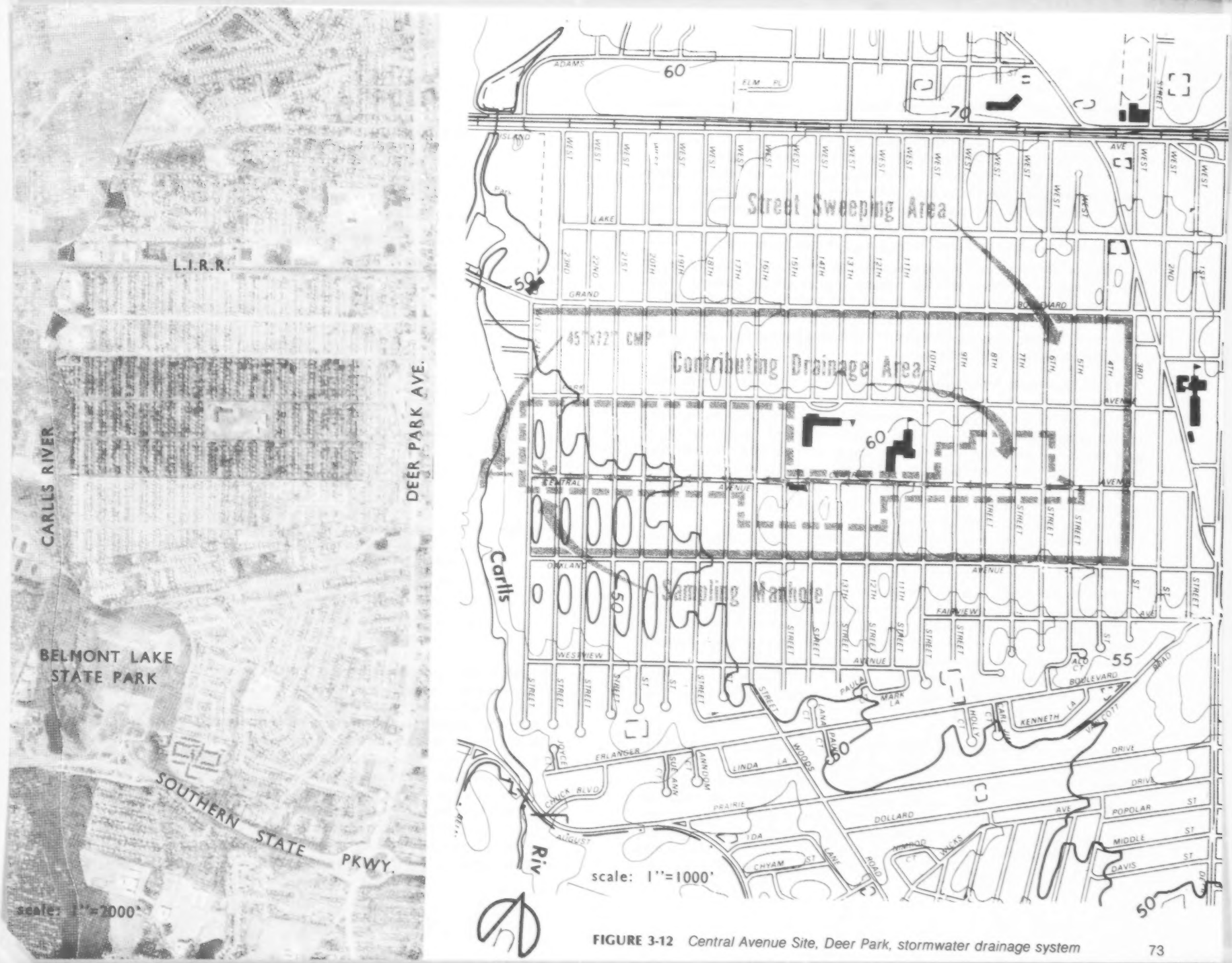


FIGURE 3-12 *Central Avenue Site, Deer Park, stormwater drainage system*

The soils underlying the study site belong to the Riverhead and Haven Series. This series consists of areas of Riverhead sandy loam and of Haven loam. The soil is well drained with medium to coarse textured soils forming a mantle of sandy loam or fine sandy loam over thick layers of coarse sand and gravel. Riverhead and Haven soils have moderate to high available moisture capacity and good internal drainage. Permeability is moderately rapid in the surface layer and in the subsoil and very rapid in the substratum. Grading operations have altered the natural topography of this area when the housing developments were constructed, leaving a gently sloping terrain.

3.3.2 Sampling Program. Stormwater runoff sampling was conducted at the last manhole in the storm drainage system located approximately 350 feet from the outlet that discharges to the Carlls River. The flow meter was installed in the 45" × 72" oval corrugated metal pipe (CMP) which provided the entire influent flow to the sampling manhole. The following paragraphs describe the sampling equipment and procedures.

3.3.2.1 Equipment. Precipitation was measured by a manual dipstick gage which was set up at the sampling site by the sampling crew. This gage was read several times throughout the duration of the storm and before each runoff sample was taken to provide data on the storm intensity and total precipitation. A recording precipitation gage at Belmont Park Headquarters was also used to obtain antecedent precipitation data. A precipitation sample was collected in two plastic buckets placed adjacent to the sampling site. The precipitation sample was analyzed for the same chemical parameters that were analyzed in the runoff samples.

The volume of stormwater runoff discharging into the Carlls River was measured by a Marsh-McBirney Velocity Modified Flow Meter, Model 265, and recorded on a 24-hour circular chart. The chart records flow in millions of gallons per day (MGD) as a function of time. The meter also measured flow in increments of one thousand gallons on a separate digital totalizer. The probe of the flow meter was installed and checked in accordance with the procedure recommended in the Marsh-McBirney operations manual. Manufacturer's guidance for upstream and downstream conditions was observed.

Portable instruments to measure pH, conductivity, D.O. (Dissolved Oxygen) and water temperature were used, and these parameters were recorded in the field at the time of sampling.

3.3.2.2 Sampling Procedures. Stormwater runoff samples were analyzed for bacteriological and chemical parameters as shown in Table 3-19. The first sample was taken when the totalizer registered 1,000 gallons of runoff. This was done to determine the significance, if any, of the "First Flush" from the runoff. The second sample was taken at the 5,000 gallon measurement. Subsequent samples were taken at each 5,000 gallon interval or multiple thereof, depending upon the intensity and duration of the storm. For extended storms, it was standard procedure to collect a sample at least once every 60 minutes. If more samples were taken than it was feasible to analyze; then, individual samples were selected that would represent the entire hydrograph as closely as possible.

Table 3-19

SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES
SAMPLING PARAMETERS AND
COLOR CODING FOR SAMPLE BOTTLES

Tape Color	Parameters	Quantity Of Sample
Red	TKN TP	125 ml
Green	$NO_3 - N$ $NH_3 - N$ $NH_2 - N$	125 ml
Blue	TIC TOC COD	125 ml
White	Suspended Solids Chloride	250 ml
Orange	Total Metals*	125 ml
——	BOD	
——	Bacteriological	

NOTES: 1) Bacteriological—T. Coli, F. Coli, F. Strep.
2) Total Metals—lead, chromium, cadmium, zinc, copper, iron manganese.
All samples preserved on ice.
In addition—1 sample of total precipitation.
*Preserved with Nitric Acid

A replicate sample was taken at one sample point during each storm event. This was used to indicate any variability between simultaneous grab samples.

Bacteria samples were collected manually by immersing a sterile container into the runoff flow; then, capping it and placing it on ice in a cooler. These samples were analyzed for total coliform, fecal coliform and fecal streptococcus within 6-18 hours of collection.

Chemical samples were collected manually in a one liter container that was immersed in the runoff flow and then dispensed into sampling bottles through a "cone splitter."

A cone splitter was used to insure even distribution of the sample, both quantitatively and qualitatively, from the one liter container to the color coded bottles that indicated the parameters to be analyzed. The cone splitter had ten hoses through which samples were dispensed. One hose was placed into each of the four color-coded 125 milliliter bottles. Two hoses were placed into the 250 milliliter bottle and the four remaining hoses were drained to waste. These samples were also packed in ice until delivery to the laboratory.

The cone splitter was rinsed with distilled water after each one liter sample was decanted through it. The one liter sample container was rinsed twice with flow from the runoff before each sample was taken. All probes from the field instruments measuring pH, conductivity, D.O. and temperature were rinsed with distilled water to prevent contamination of the samples.

All analyses were performed by the Suffolk County Department of Health Services—Public Health Laboratory in Hauppauge, New York. The methods used conformed to the *Quality Assurance Project Plan for the Nassau/Suffolk Urban Runoff Project*, March 1981. Runoff samples were analyzed as grab samples, and the results were used to calculate the Event Mean Concentration (EMC), load and load factor.

After reviewing the data from the first few storm events, it was decided that tests for BOD, COD, and the heavy metal series should be eliminated since these parameters were not found in sufficient magnitude to warrant continued study. Table 3-20 indicates the amount and type of laboratory analyses performed on the runoff and precipitation. The number of samples taken during each event varied from 6 to 21, including a replicate sample.

3.3.3 Characteristics of Sampled Storms. A total of 27 storms were sampled at the Central Avenue Street Sweeping site. The first nineteen storm events occurred before intensive street cleaning was initiated; and the remaining eight storms, after intensive street sweeping began. Nine storms were surveyed in autumn, five in winter, eight in spring and five in summer. Fewer storms were sampled during the summer months because the short duration thunder storms are scattered and more difficult to predict than the broad frontal winter storms.

Table 3-21 presents some of the basic characteristics of each storm. Storm characteristics include the storm duration, amount of precipitation, maximum intensity in a 15-minute interval, acre-feet of runoff, antecedent dry days, and time since the last street sweeping. The storms varied from 0.12 to 1.97 inches of total precipitation.

3.3.4 Analysis of Data

3.3.4.1 Relationship of Runoff to Precipitation. Table 3-22 presents precipitation, runoff and infiltration values, as well as the calculated runoff coefficient, for the 27 storms studied. Relative amounts of infiltration and runoff are graphically depicted in Fig. 3-13.

Using the data from 26 events, a linear regression was performed relating rainfall to runoff. The resulting line of best fit is presented in Fig. 3-14. The results may be somewhat biased due to the fact that only one storm greater than one inch was included. Typically, graphs of rainfall/runoff relationships are curved, indicating an increasing percentage of runoff with increasing rainfall. The storm of 2/3/82 was excluded because it occurred after an extremely cold Janaury with temperatures at or below 0°F much of the time. Frozen ground conditions had obviously increased the amount of runoff for this storm substantially despite a relatively low rainfall intensity.

The average runoff coefficient for the 26 storms analyzed is 0.236, somewhat higher than the 20% of impervious surface. Eleven of the 26 storms had a runoff coefficient greater than 0.25 with four greater than 0.35. This demonstrates that, even in a drainage area with relatively permeable soils and flat topography, a portion of the runoff often comes from precipitation falling on pervious surfaces. The percentage of the runoff from the pervious and impervious surfaces varies depending on total precipitation, rainfall intensity, antecedent precipitation, frozen ground conditions, etc.

3.3.4.2 Evaluation of Intensive Street Sweeping as a Control Measure. One measure selected for evaluation was intensive street cleaning. The underlying premise was that if a significant amount of the roadway sediment to which bacteria adhere could be removed, then the overall bacterial load entrained in stormwater runoff, and transported to the surface waters, would be substantially reduced.

The Town of Babylon Highway Department normally cleans the streets five times a year (April, June, September, October and November), using Elgin-Pelican III and Mobil Series IT E4 mechanical broom sweepers. Sweepers unload to a dump truck which transports materials to the town landfill.

For purposes of the NURP investigation, the Town of Babylon Highway Department, acting under contract to SCDHS, cleaned the streets of the Central Avenue drainage area once a week, employing a two-day procedure. The side of the street with odd numbered houses was cleaned one day; that with even numbered houses the next day.

The intensive street sweeping program began the week of March 22, 1982 and ended the first week of November, 1982. A mechanical broom sweeper cleaned the area next to the curb, followed by a second sweeper, which was offset a few feet from the curb. As expected, the first time the streets were cleaned it took a prolonged amount of time because of the heavy accumulation of sand from winter deicing practices. Subsequent sweepings, except for 4/14 and 4/15, took a much shorter time because of the relatively small amount of accumulated roadway debris. Table 3-23 indicates the amount of material collected for each cleaning.

Table 3-20

CENTRAL AVENUE SITE
AMOUNT AND TYPE OF ANALYSES PERFORMED

Date	Precipitation	Runoff
11-18-80	1S	11B, 11S
12-09-80	1S	6B, 6S
02-02-81	1S	14B, 14S
03-11-81	1S	9B, 9S
03-30-81	1S	15B, 15S
04-14-81	1S	14B, 14S
05-11-81	1S	9B, 9S
06-02-81	1S	10B, 10S
07-28-81	1S	11B, 11S
10-23-81		21B
10-27-81	1S	13B, 13S
11-06-81		14B
11-20-81		13B
12-01-81	1S	13B, 13S
12-14-81	1S	15B, 15S
02-03-82	1S	15B, 15S
02-09-82		10B
03-16-82	1S	15B, 15S
03-31-82	1S	9B, 9S
04-26-82	1S	10B, 10S
06-01-82	1S	12B, 12S
06-16-82	1S	10B, 10S
06-29-82	1S	8B, 8S
08-09-82	1S	10B, 10S
09-01-82	1S	13B, 13S
10-25-82	1S	14B, 14S

B—Bacteria Analysis
S—Standard Chemical Analysis

Table 3-21

CENTRAL AVENUE SITE
STORM CHARACTERISTICS

I. Without Intensive Street Cleaning

Date	Duration (hrs)	Precip. (in.)	Maximum Intensity (in/15 min)	Runoff (Acre-ft.)	Antecedent Dry Days (≤0.1 in)	Time Since Last Street Cleaning (Days)
11-18-80	6.80	0.50	0.07	0.283	14	20
12-09-80	4.00	0.16	0.05	0.063	6	24
02-02-81	7.10	0.57	0.08	0.632	24	79
03-11-81	2.33	0.14	0.02	0.117	4	116
03-30-81	6.22	0.44	0.03	0.444	23	135
04-14-81	5.55	0.66	0.14	1.092	8	150
05-11-81	8.50	0.19	0.03	0.111	9	14
06-02-81	3.93	0.31	0.05	0.235	2	37
06-25-81	1.08	0.45	0.26	0.924	5	8
07-28-81	0.17	0.23	0.22	0.320	7	41
10-23-81	8.66	0.97	0.08	1.416	4	53
10-27-81	6.15	0.26	0.04	0.472	1	57
11-06-81	5.00	0.52	0.06	0.666	9	67
11-20-81	0.93	0.48	0.20	0.988	2	5
12-01-81	6.72	0.55	0.05	0.832	10	16
12-14-81	5.67	0.41	0.04	0.637	5	27
02-03-82	11.63	1.15	0.07	5.750	2	80
02-09-82	3.75	0.12	0.02	0.189	6	86
03-16-82	8.00	0.41	0.06	0.797	5	121

II. With Intensive Street Cleaning

Date	Duration (hrs)	Precip. (in.)	Maximum Intensity (in/15 min)	Runoff (Acre-ft.)	Antecedent Dry Days (≤0.1 in)	Time Since Last Street Cleaning (Days)
03-31-82	4.83	0.25	0.05	0.368	5	0
04-26-82	10.00	0.93	0.12	1.670	8	4
06-01-82	5.50	1.97	0.40	5.440	3	5
06-16-82	1.75	0.18	0.06	0.219	3	0
06-29-82	7.12	0.37	0.08	0.565	4	5
08-09-82	0.75	0.48	0.24	1.035	11	4
09-01-82	3.75	0.44	0.10	0.644	7	5
10-25-82	7.50	0.55	0.08	1.050	16	4

Table 3-22

CENTRAL AVENUE SITE
PRECIPITATION, RUNOFF, INFILTRATION, RUNOFF COEFFICIENT

Date	Precip. (inches)	Runoff (inches)	Infiltration (inches)	Runoff Coefficient C
11-18-80	0.50	0.046	0.454	0.092
12-09-80	0.16	0.010	0.150	0.063
02-02-81	0.57	0.104	0.466	0.183
03-11-81	0.14	0.019	0.121	0.136
03-30-81	0.44	0.073	0.367	0.166
04-14-81	0.66	0.180	0.480	0.271
05-11-81	0.19	0.018	0.172	0.095
06-02-81	0.31	0.039	0.271	0.126
06-25-81	0.45	0.152	0.298	0.337
07-28-81	0.22	0.053	0.167	0.241
10-23-81	0.97	0.233	0.737	0.240
10-27-81	0.26	0.078	0.182	0.298
11-06-81	0.52	0.110	0.410	0.211
11-20-81	0.48	0.162	0.318	0.388
12-01-81	0.55	0.137	0.413	0.249
12-14-81	0.41	0.105	0.305	0.256
02-03-82	1.15	0.944	0.206	0.821
02-09-82	0.12	0.031	0.089	0.259
03-16-82	0.42	0.131	0.279	0.319
03-31-82	0.25	0.064	0.186	0.256
04-26-82	0.93	0.295	0.635	0.317
06-01-82	1.97	0.776	1.194	0.394
06-16-82	0.18	0.036	0.144	0.202
06-29-82	0.37	0.075	0.295	0.201
08-09-82	0.48	0.170	0.310	0.354
09-01-82	0.44	0.106	0.334	0.241
10-25-82	0.55	0.172	0.378	0.313

3.3.4.3 Load Reduction Analysis. A primary concern of the surface waters portion of the Long Island NURP was to investigate the effectiveness of various control measures to reduce bacterial loads in runoff. If effective, then the feasibility, acceptability and implementability of such measures would be determined. Bacterial load reductions are necessary if receiving bay waters, presently uncertified for shellfishing because they exceed the coliform standards, are to meet these standards and reopen for shellfishing.

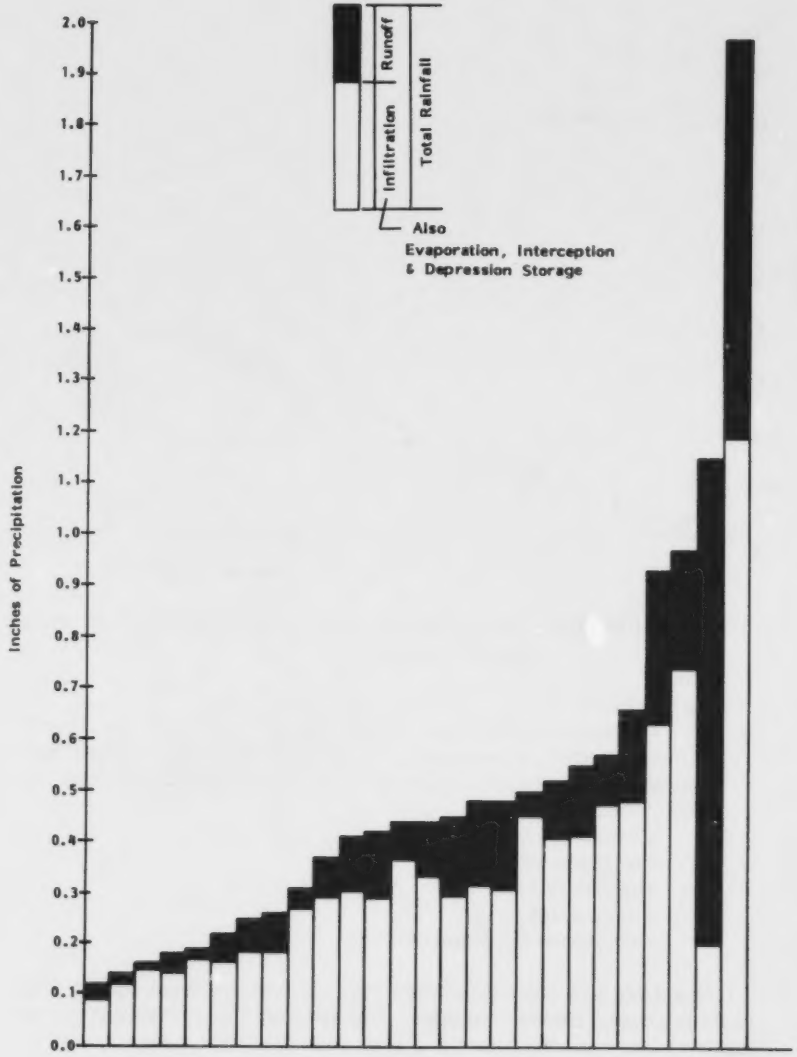


FIGURE 3-13 *Central Avenue Site: Amounts of runoff and infiltration relative to total rainfall for sampled storm events*

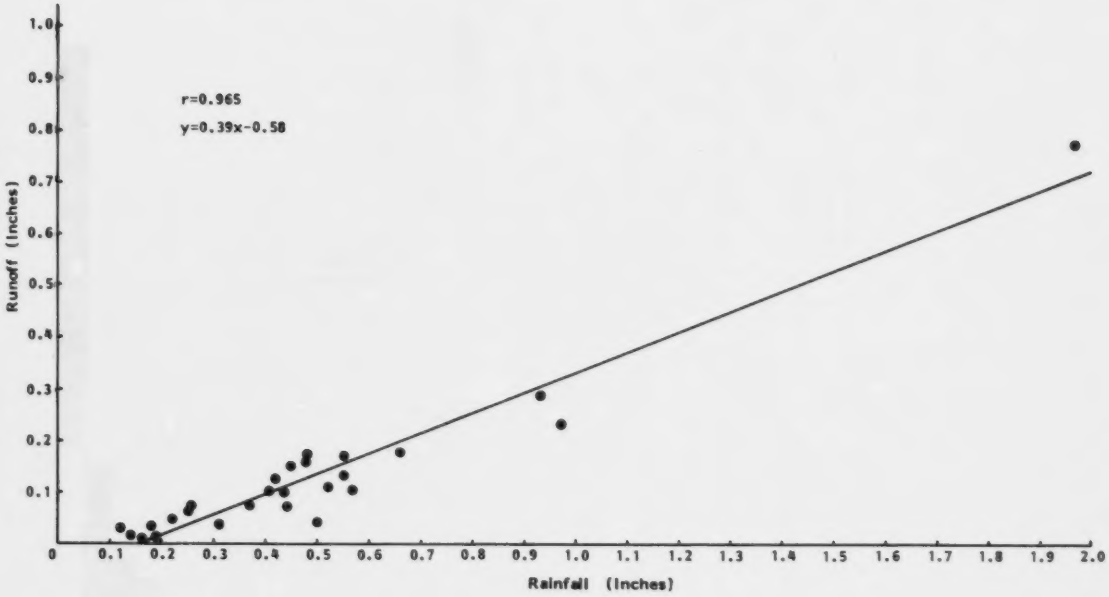


FIGURE 3-14 *Central Avenue Site: Relationship of runoff to rainfall for sampled storms*

(a) Bacteria

Consistent with the main objective, the reduction of coliform counts to meet shellfishing standards, the load reduction analysis began with the review of the bacteriological data. This analysis included consideration of the following:

- time of year
- total precipitation
- rainfall intensity
- antecedent rainfall
- time since last street cleaning

Tables 3-24, 3-25 and 3-26 present the total coliform, fecal coliform and fecal streptococci data for the storm events sampled. These tables contain the results of storm events before and after intensive street sweeping was instituted.

Table 3-27 presents the ratios of fecal coliform to fecal streptococci and fecal coliform to total coliform. The fecal coliform to fecal streptococci ratio was generally below 0.7 except for two events. A ratio below 0.7 indicates that the fecal pollution is derived from warm-blooded animals, other than humans.

Table 3-23

CENTRAL AVENUE SITE
CUBIC YARDS OF ROAD DEBRIS REMOVED BY STREET SWEEPING*

Date	Cubic Yards	Date	Cubic Yards
03-22-82	No Data	07-22-82	1
03-23-82	No Data	07-29-82	2
03-31-82	No Data	08-04-82	1
04-01-82	No Data	08-05-82	1
04-14-82	6**	08-11-82	1
04-15-82	4**	08-12-82	1
04-21-82	1	08-18-82	2
04-22-82	1	08-19-82	1
04-28-82	1	08-25-82	1
04-29-82	1	08-26-82	1
05-05-82	1	09-02-82	1
05-06-82	1	09-03-82	1
05-11-82	1	09-08-82	2
05-12-82	1	09-09-82	2
05-19-82	1.5	09-15-82	1
05-20-82	1.5	09-16-82	1.5
05-26-82	1	09-22-82	1
05-27-82	2.5	09-23-82	1
06-02-82	1	09-29-82	2
06-03-82	1	09-30-82	2
06-09-82	1	10-06-82	1
06-10-82	1	10-07-82	1
06-16-82	1	10-13-82	1.5
06-17-82	1	10-14-82	1.5
06-22-82	1	10-20-82	2
06-23-82	1	10-21-82	2
06-30-82	1	10-27-82	8***
07-01-82	2	10-28-82	6***
07-02-82	1	11-04-82	12***

* Estimates of equipment operator.
** Indicates street sweeping following sanding for snow storm.
*** Includes collection of leaves.

Source: Town of Bablyon Highway Department.

Table 3-24

CENTRAL AVENUE SITE
TOTAL COLIFORM: EMC, LOAD AND LOAD FACTOR

I. Without Intensive Street Cleaning

Date	Precip. (in.)	Runoff (Acre-ft.)	EMC (MPN/100ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	$.129 \times 10^{5}$	$.414 \times 10^{11}$	$.567 \times 10^{8}$	$.113 \times 10^{10}$	20
12-09-80	0.16	0.063	$.666 \times 10^{4}$	$.413 \times 10^{10}$	$.566 \times 10^{8}$	$.354 \times 10^{8}$	24
02-02-81	0.57	0.632	$.546 \times 10^{4}$	$.422 \times 10^{11}$	$.578 \times 10^{8}$	$.101 \times 10^{10}$	79
03-11-81	0.14	0.117	$.147 \times 10^{4}$	$.188 \times 10^{10}$	$.258 \times 10^{8}$	$.184 \times 10^{8}$	116
03-30-81	0.44	0.444	$.497 \times 10^{4}$	$.267 \times 10^{11}$	$.360 \times 10^{8}$	$.831 \times 10^{8}$	135
04-14-81	0.66	1.092	$.388 \times 10^{4}$	$.476 \times 10^{11}$	$.652 \times 10^{8}$	$.988 \times 10^{8}$	150
05-11-81	0.19	0.111	$.209 \times 10^{8}$	$.253 \times 10^{12}$	$.346 \times 10^{10}$	$.182 \times 10^{11}$	14
06-02-81	0.31	0.235	$.240 \times 10^{8}$	$.690 \times 10^{12}$	$.945 \times 10^{10}$	$.305 \times 10^{11}$	37
06-25-81	0.45	0.924	$.206 \times 10^{8}$	$.236 \times 10^{13}$	$.323 \times 10^{11}$	$.718 \times 10^{11}$	8
07-28-81	0.22	0.320	$.124 \times 10^{8}$	$.510 \times 10^{12}$	$.699 \times 10^{10}$	$.318 \times 10^{11}$	41
10-23-81	0.97	1.416	$.542 \times 10^{8}$	$.946 \times 10^{12}$	$.130 \times 10^{11}$	$.132 \times 10^{11}$	53
10-27-81	0.26	0.472	$.188 \times 10^{8}$	$.110 \times 10^{13}$	$.150 \times 10^{11}$	$.578 \times 10^{11}$	57
11-06-81	0.52	0.666	$.643 \times 10^{5}$	$.529 \times 10^{12}$	$.724 \times 10^{10}$	$.139 \times 10^{11}$	67
11-20-81	0.48	0.988	$.596 \times 10^{5}$	$.726 \times 10^{12}$	$.994 \times 10^{10}$	$.207 \times 10^{11}$	5
12-01-81	0.55	0.832	$.615 \times 10^{4}$	$.632 \times 10^{11}$	$.866 \times 10^{8}$	$.157 \times 10^{10}$	16
12-14-81	0.41	0.637	$.790 \times 10^{3}$	$.621 \times 10^{10}$	$.850 \times 10^{8}$	$.207 \times 10^{9}$	27
02-03-82	1.15	5.750	$.240 \times 10^{4}$	$.170 \times 10^{12}$	$.233 \times 10^{10}$	$.203 \times 10^{10}$	80
02-09-82	0.12	0.189	$.384 \times 10^{3}$	$.895 \times 10^{9}$	$.123 \times 10^{8}$	$.103 \times 10^{8}$	86
03-16-82	0.42	0.797	$.209 \times 10^{4}$	$.210 \times 10^{11}$	$.282 \times 10^{8}$	$.671 \times 10^{8}$	121

II. With Intensive Street Cleaning

Date	Precip. (in.)	Runoff (Acre-ft.)	EMC (MPN/100ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	$.761 \times 10^{4}$	$.366 \times 10^{11}$	$.501 \times 10^{8}$	$.200 \times 10^{10}$	0
04-26-82	0.93	1.670	$.832 \times 10^{4}$	$.184 \times 10^{12}$	$.252 \times 10^{10}$	$.271 \times 10^{10}$	4
06-01-82	1.97	5.440	$.240 \times 10^{8}$	$.140 \times 10^{14}$	$.191 \times 10^{12}$	$.971 \times 10^{11}$	5
06-16-82	0.18	0.219	$.880 \times 10^{5}$	$.240 \times 10^{12}$	$.329 \times 10^{10}$	$.183 \times 10^{11}$	0
06-29-82	0.37	0.565	$.122 \times 10^{8}$	$.681 \times 10^{12}$	$.934 \times 10^{10}$	$.252 \times 10^{11}$	5
08-09-82	0.48	1.035	$.234 \times 10^{8}$	$.299 \times 10^{13}$	$.410 \times 10^{11}$	$.850 \times 10^{11}$	4
09-01-82	0.44	0.644	$.134 \times 10^{8}$	$.106 \times 10^{13}$	$.146 \times 10^{11}$	$.331 \times 10^{11}$	5
10-25-82	0.55	1.050	$.806 \times 10^{8}$	$.106 \times 10^{13}$	$.145 \times 10^{11}$	$.263 \times 10^{11}$	4

Table 3-25

CENTRAL AVENUE SITE
FECAL COLIFORM: EMC, LOAD AND LOAD FACTOR

I. Without Intensive Street Cleaning

Date	Precip. (in.)	Runoff (Acre-ft.)	EMC (MPN/100ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	$.283 \times 10^{4}$	$.764 \times 10^{10}$	$.105 \times 10^{9}$	$.210 \times 10^{9}$	20
12-09-80	0.16	0.063	$.181 \times 10^{4}$	$.112 \times 10^{10}$	$.154 \times 10^{8}$	$.961 \times 10^{8}$	24
02-02-81	0.57	0.632	$.275 \times 10^{4}$	$.213 \times 10^{11}$	$.292 \times 10^{9}$	$.511 \times 10^{9}$	79
03-11-81	0.14	0.117	$.400 \times 10^{3}$	$.512 \times 10^{9}$	$.700 \times 10^{7}$	$.501 \times 10^{8}$	116
03-30-81	0.44	0.444	$.302 \times 10^{3}$	$.162 \times 10^{10}$	$.222 \times 10^{8}$	$.505 \times 10^{8}$	135
04-14-81	0.66	1.092	$.176 \times 10^{4}$	$.216 \times 10^{11}$	$.295 \times 10^{9}$	$.448 \times 10^{8}$	150
05-11-81	0.19	0.111	$.415 \times 10^{5}$	$.502 \times 10^{11}$	$.688 \times 10^{9}$	$.362 \times 10^{10}$	14
06-02-81	0.31	0.235	$.934 \times 10^{5}$	$.269 \times 10^{12}$	$.368 \times 10^{10}$	$.119 \times 10^{10}$	37
06-25-81	0.45	0.924	$.279 \times 10^{5}$	$.320 \times 10^{12}$	$.438 \times 10^{10}$	$.973 \times 10^{10}$	8
07-28-81	0.22	0.320	$.311 \times 10^{5}$	$.128 \times 10^{12}$	$.175 \times 10^{10}$	$.797 \times 10^{10}$	41
10-23-81	0.97	1.416	$.431 \times 10^{4}$	$.753 \times 10^{11}$	$.103 \times 10^{10}$	$.106 \times 10^{10}$	53
10-27-81	0.26	0.472	$.197 \times 10^{5}$	$.115 \times 10^{12}$	$.157 \times 10^{10}$	$.604 \times 10^{10}$	57
11-06-81	0.52	0.666	$.743 \times 10^{4}$	$.611 \times 10^{11}$	$.837 \times 10^{9}$	$.161 \times 10^{10}$	67
11-20-81	0.48	0.988	$.524 \times 10^{4}$	$.640 \times 10^{11}$	$.877 \times 10^{9}$	$.183 \times 10^{10}$	5
12-01-81	0.55	0.832	$.135 \times 10^{4}$	$.139 \times 10^{11}$	$.190 \times 10^{9}$	$.345 \times 10^{9}$	16
12-14-81	0.41	0.637	$.387 \times 10^{3}$	$.304 \times 10^{10}$	$.417 \times 10^{8}$	$.758 \times 10^{8}$	27
02-03-82	1.15	5.750	$.155 \times 10^{4}$	$.109 \times 10^{12}$	$.151 \times 10^{10}$	$.131 \times 10^{10}$	80
02-09-82	0.12	0.189	$.250 \times 10^{3}$	$.583 \times 10^{9}$	$.799 \times 10^{7}$	$.666 \times 10^{8}$	86
03-16-82	0.42	0.797	$.743 \times 10^{3}$	$.730 \times 10^{10}$	$.999 \times 10^{8}$	$.238 \times 10^{9}$	121

II. With Intensive Street Cleaning

Date	Precip. (in.)	Runoff (Acre-ft.)	EMC (MPN/100ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	$.690 \times 10^{4}$	$.332 \times 10^{11}$	$.454 \times 10^{9}$	$.182 \times 10^{10}$	0
04-26-82	0.93	1.670	$.137 \times 10^{4}$	$.302 \times 10^{11}$	$.414 \times 10^{9}$	$.445 \times 10^{9}$	4
06-01-82	1.97	5.440	$.366 \times 10^{5}$	$.213 \times 10^{13}$	$.292 \times 10^{11}$	$.148 \times 10^{11}$	5
06-16-82	0.18	0.219	$.145 \times 10^{5}$	$.405 \times 10^{11}$	$.555 \times 10^{9}$	$.309 \times 10^{10}$	0
06-29-82	0.37	0.565	$.407 \times 10^{5}$	$.228 \times 10^{12}$	$.312 \times 10^{10}$	$.843 \times 10^{10}$	5
08-09-82	0.48	1.035	$.154 \times 10^{5}$	$.196 \times 10^{12}$	$.269 \times 10^{10}$	$.560 \times 10^{10}$	4
09-01-82	0.44	0.644	$.181 \times 10^{5}$	$.144 \times 10^{12}$	$.197 \times 10^{10}$	$.449 \times 10^{10}$	5
10-25-82	0.55	1.050	$.200 \times 10^{5}$	$.259 \times 10^{12}$	$.355 \times 10^{10}$	$.645 \times 10^{10}$	4

Table 3-26

CENTRAL AVENUE SITE
FECAL STREPTOCOCCI: EMC, LOAD AND LOAD FACTOR

I. Without Intensive Street Cleaning

Date	Precip. (in.)	Runoff (Acre-ft.)	EMC (MPN/100ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	$.281 \times 10^{6}$	$.902 \times 10^{11}$	$.123 \times 10^{10}$	$.247 \times 10^{10}$	20
12-09-80	0.16	0.063	$.263 \times 10^{6}$	$.146 \times 10^{11}$	$.200 \times 10^{9}$	$.125 \times 10^{10}$	24
02-02-81	0.57	0.632	$.732 \times 10^{6}$	$.567 \times 10^{12}$	$.777 \times 10^{10}$	$.136 \times 10^{11}$	79
03-11-81	0.14	0.117	$.255 \times 10^{6}$	$.326 \times 10^{10}$	$.447 \times 10^{8}$	$.319 \times 10^{9}$	116
03-30-81	0.44	0.444	$.237 \times 10^{6}$	$.127 \times 10^{11}$	$.174 \times 10^{9}$	$.395 \times 10^{9}$	135
04-14-81	0.66	1.092	$.130 \times 10^{6}$	$.160 \times 10^{12}$	$.219 \times 10^{10}$	$.330 \times 10^{10}$	150
05-11-81	0.19	0.111	$.602 \times 10^{6}$	$.728 \times 10^{11}$	$.998 \times 10^{9}$	$.525 \times 10^{10}$	14
06-02-81	0.31	0.235	$.533 \times 10^{6}$	$.154 \times 10^{12}$	$.210 \times 10^{10}$	$.678 \times 10^{10}$	37
06-25-81	0.45	0.924	$.163 \times 10^{6}$	$.187 \times 10^{13}$	$.256 \times 10^{11}$	$.569 \times 10^{11}$	8
07-28-81	0.22	0.320	$.171 \times 10^{6}$	$.704 \times 10^{11}$	$.964 \times 10^{9}$	$.438 \times 10^{10}$	41
10-23-81	0.97	1.416	$.251 \times 10^{6}$	$.433 \times 10^{12}$	$.593 \times 10^{10}$	$.612 \times 10^{10}$	53
10-27-81	0.26	0.472	$.497 \times 10^{6}$	$.289 \times 10^{12}$	$.369 \times 10^{10}$	$.152 \times 10^{11}$	57
11-06-81	0.52	0.666	$.155 \times 10^{6}$	$.128 \times 10^{12}$	$.175 \times 10^{10}$	$.452 \times 10^{10}$	67
11-20-81	0.48	0.988	$.136 \times 10^{6}$	$.165 \times 10^{12}$	$.227 \times 10^{10}$	$.472 \times 10^{10}$	5
12-01-81	0.55	0.832	$.117 \times 10^{6}$	$.120 \times 10^{12}$	$.164 \times 10^{10}$	$.298 \times 10^{10}$	16
12-14-81	0.41	0.637	$.172 \times 10^{6}$	$.135 \times 10^{11}$	$.185 \times 10^{9}$	$.336 \times 10^{9}$	27
02-03-82	1.15	5.750	$.431 \times 10^{6}$	$.305 \times 10^{13}$	$.419 \times 10^{11}$	$.364 \times 10^{11}$	80
02-09-82	0.12	0.189	$.410 \times 10^{6}$	$.957 \times 10^{10}$	$.130 \times 10^{9}$	$.109 \times 10^{10}$	86
03-16-82	0.42	0.797	$.643 \times 10^{6}$	$.630 \times 10^{12}$	$.865 \times 10^{10}$	$.206 \times 10^{11}$	121

II. With Intensive Street Cleaning

Date	Precip. (in.)	Runoff (Acre-ft.)	EMC (MPN/100ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	$.206 \times 10^{6}$	$.990 \times 10^{11}$	$.136 \times 10^{10}$	$.543 \times 10^{10}$	0
04-26-82	0.93	1.670	$.971 \times 10^{6}$	$.215 \times 10^{12}$	$.294 \times 10^{10}$	$.316 \times 10^{10}$	4
06-01-82	1.97	5.440	$.940 \times 10^{6}$	$.547 \times 10^{13}$	$.749 \times 10^{11}$	$.380 \times 10^{11}$	5
06-16-82	0.18	0.219	$.755 \times 10^{6}$	$.206 \times 10^{12}$	$.283 \times 10^{10}$	$.157 \times 10^{11}$	0
06-29-82	0.37	0.565	$.991 \times 10^{6}$	$.554 \times 10^{12}$	$.759 \times 10^{10}$	$.205 \times 10^{11}$	5
08-09-82	0.48	1.035	$.457 \times 10^{6}$	$.583 \times 10^{12}$	$.799 \times 10^{10}$	$.167 \times 10^{11}$	4
09-01-82	0.44	0.644	$.640 \times 10^{6}$	$.480 \times 10^{12}$	$.657 \times 10^{10}$	$.149 \times 10^{11}$	5
10-25-82	0.55	1.050	$.772 \times 10^{6}$	$.100 \times 10^{13}$	$.137 \times 10^{11}$	$.249 \times 10^{11}$	4

Results of a survey conducted in the study area implicated the dog population as a significant source of the fecal coliform load. However, because the fecal coliform to fecal streptococci ratios of the runoff samples were significantly higher than the FC/FS = 0.002 for dog feces cited in the *Long Island 208 Study*, the question of the presence of other sources that might account for the higher ratios is as yet unresolved. The fecal coliform to total coliform ratios suggest that a large portion of the total coliform load is non-fecal in origin. Since the computed runoff coefficients indicated that runoff was derived from both impervious and pervious surfaces, the non-fecal coliform may be soil bacteria from the lawn and garden areas.

These bacteriological results also indicate that the number of fecal streptococci exhibit significant fluctuation between seasons. The numbers of total coliform and fecal coliform exhibit even larger seasonal variations (Table 3-28). This table also shows that the average load factors are somewhat lower than the factors given in the Long Island 208 study. This may be due in large part to the seasonal variation, since sampling for the 208 study was done mostly during warm weather.

A preliminary examination of the data within the context of the five criteria listed above does not indicate the attainment of any definitive and consistent improvement resulting from intensive street sweeping.

Additional information regarding the value of street sweeping or other street cleaning methods was obtained through review of data for the storm event of 10/23/81 -10/24/81 (Figs. 3-15 and 3-16). This storm was first analyzed in its entirety as a 0.97 inch rainfall and then separated into an initial 0.24 inch storm followed by a 0.73 inch storm. The time between rainfalls was approximately two hours, and the time between hydrographs was approximately one hour. There were ten grab samples collected during the period covered by each hydrograph, thus providing a total of twenty sample points for the entire storm.

The purpose of reviewing these storm data was to determine whether the flushing action from the initial 0.24 inch storm was effective in removing surface debris from the streets, thereby reducing bacterial concentrations during the second storm.

A visual inspection of the pollutograph bacteria counts versus time, (Fig. 3-16) shows that there was a marked increase in the number of bacteria in the runoff samples during the first intense period of rain. When this period had passed, the bacteria counts fluctuated within the bounds of a somewhat narrower interval for each parameter. Even when the rain intensity increased during the second phase of the storm, the bacteria counts did not increase as they had for the initial rainfall.

Table 3-29 presents the bacteriological data for the entire 0.97 inch storm along with a separate data analysis for the 0.24 inch and 0.73 inch storms. A review of the EMC's leads to the conclusion that there was indeed a significant cleaning effect, "first flush", from the initial rainfall. The second storm produced greater total loads because the much higher runoff volume for the second storm offset its lower EMC's. Furthermore, when the storm data are adjusted

Table 3-27

CENTRAL AVENUE SITE
RATIOS OF FECAL COLIFORM/FECAL STREP
AND FECAL COLIFORM/TOTAL COLIFORM

I. Without Intensive Street Cleaning

Date	Fecal Coliform/ Fecal Strep	Fecal Coliform/ Total Coliform
11-18-80	0.85	0.185
12-09-80	0.690	0.271
02-02-81	0.380	0.510
03-11-81	0.160	0.271
03-30-81	0.127	0.060
04-14-81	0.140	0.450
05-11-81	0.690	0.198
06-02-81	1.750	0.390
06-25-81	0.170	0.135
07-28-81	1.820	0.250
10-23-81	0.160	0.080
10-27-81	0.400	0.105
11-06-81	0.480	0.114
11-20-81	0.390	0.087
12-01-81	0.120	0.217
12-14-81	0.230	0.490
02-03-82	0.040	0.625
02-09-82	0.060	0.650
03-16-82	0.180	0.360

II. With Intensive Street Cleaning

Date	Fecal Coliform/ Fecal Strep	Fecal Coliform/ Total Coliform
03-31-82	0.340	0.910
04-26-82	0.140	0.164
06-01-82	0.390	0.152
06-16-82	0.190	0.164
06-29-82	0.410	0.333
08-09-82	0.340	0.066
09-01-82	0.301	0.136
10-25-82	0.259	0.248

Table 3-28

CENTRAL AVENUE SITE
WARM WEATHER, COLD WEATHER AND L.I. 208 STUDY
BACTERIAL LOAD FACTORS

Bacterial Parameter	Warm Weather Average (MPN/AC/IN)	Cold Weather Average (MPN/AC/IN)	Warm Weather / Cold Weather Ratio	NURP Average (MPN/AC/IN)	L.I. 208 Study (MPN/AC/IN)	L.I. 208 Study / NURP Ratio
Total Coliform	0.438×10^{11}	0.323×10^{10}	14/1	0.235×10^{11}	0.602×10^{11}	3/1
Fecal Coliform	0.698×10^{10}	0.580×10^{9}	12/1	0.378×10^{10}	0.102×10^{11}	3/1
Non-Fecal Coliform	0.368×10^{11}	0.265×10^{10}	14/1			
Fecal Strep	0.185×10^{11}	0.642×10^{10}	3/1	0.125×10^{11}	No Data	——
FC/FS	0.38	0.09	4/1			

Warm Weather = May–October
Cold Weather = November–April

Table 3-29

CENTRAL AVENUE SITE
TOTAL COLIFORM, FECAL COLIFORM, FECAL STREP LOAD FACTORS
STORM EVENT OF 10/23/81–10/24/81

	Precip.	Runoff (Acre-ft)	EMC (MPN/100 ml)	Total Load (MPN)	Unit Load (MPN/AC)	Load Factor (MPN/AC/IN)
Entire Storm	0.97	1.416				
Total Coliform			$.542 \times 10^{5}$	$.946 \times 10^{12}$	$.130 \times 10^{11}$	$.134 \times 10^{11}$
Fecal Coliform			$.431 \times 10^{4}$	$.753 \times 10^{11}$	$.103 \times 10^{10}$	$.106 \times 10^{10}$
Fecal Strep			$.251 \times 10^{5}$	$.438 \times 10^{12}$	$.600 \times 10^{10}$	$.618 \times 10^{10}$
1st Hydrograph	0.24	0.244				
Total Coliform			$.978 \times 10^{5}$	$.294 \times 10^{12}$	$.403 \times 10^{10}$	$.168 \times 10^{11}$
Fecal Coliform			$.678 \times 10^{4}$	$.204 \times 10^{11}$	$.280 \times 10^{9}$	$.117 \times 10^{10}$
Fecal Strep			$.379 \times 10^{5}$	$.114 \times 10^{12}$	$.156 \times 10^{10}$	$.650 \times 10^{10}$
2nd Hydrograph	0.73	1.160				
Total Coliform			$.479 \times 10^{5}$	$.686 \times 10^{12}$	$.939 \times 10^{10}$	$.129 \times 10^{11}$
Fecal Coliform			$.391 \times 10^{4}$	$.559 \times 10^{11}$	$.766 \times 10^{9}$	$.104 \times 10^{10}$
Fecal Strep			$.229 \times 10^{5}$	$.329 \times 10^{12}$	$.450 \times 10^{10}$	$.616 \times 10^{10}$

to an inch of rain, the load factors, (MPN/AC/IN) closely approximate each other.

These results are indicative of the caution required in interpreting runoff data.

Another important consideration in evaluating the efficacy of street cleaning is that runoff for the study area, as shown in the determination of runoff coefficients, is contributed by both the pervious and impervious surfaces, to an extent depending on storm characteristics.

The data were reviewed by a NURP national consultant (Driscoll, 1983), and the following evaluation was made:

Because of the natural variability, the use of proability distributions is of considerable value in interpetation. Given the constraints of small data sets, the analysis shows that the data are reasonably log-normal.
Since analyses of very large data bases in the NURP program indicate runoff and loads are log normal, the statistics required were developed based on the underlying distributions being log normal.
The storms in the intensive street cleaning *data base are considerably larger than those in the* without street cleaning *data base. For this reason it is inappropriate to make comparisons on the basis of loads, which are strongly influenced by runoff volume.*
A check of correlation between runoff volumes and EMC's leads to the conclusion that there is no significant correlation between the two (Table 3-30). This justifies a comparison made on the basis of EMC's, despite the differences in storm size.

On the basis of the above, the results of an evaluation of the data are summarized briefly by the comments which follow and the tables which accompany them.

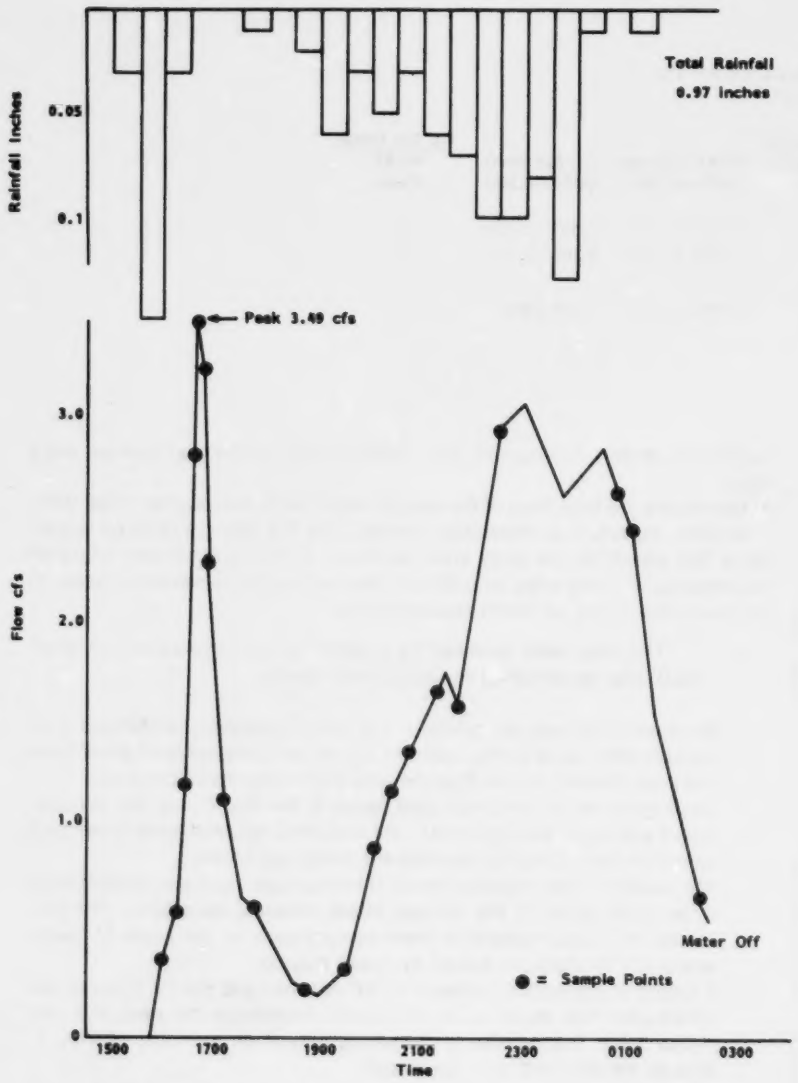


FIGURE 3-15 *Central Avenue Site: Rainfall hyetograph and runoff hydrograph Storm event 10-23/24-82.*

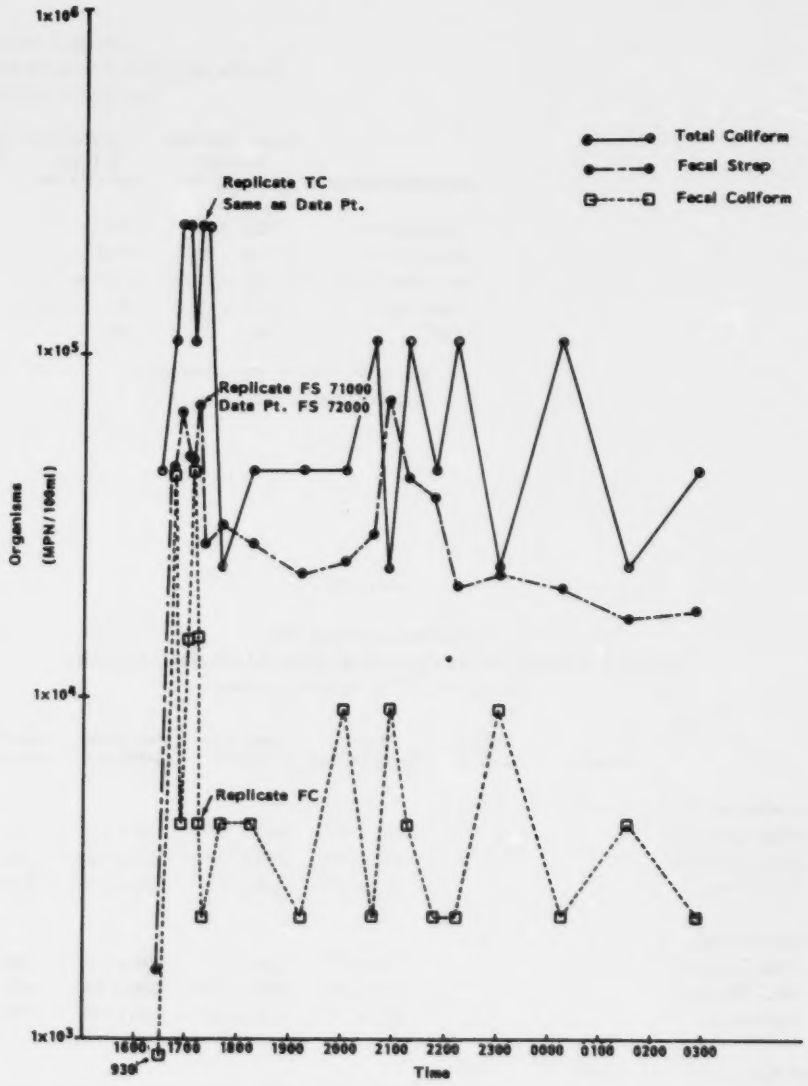


FIGURE 3-16 *Central Avenue Site: Total coliform, fecal coliform, and fecal strep pollutographs: Storm event 10-23/24-82*

When data are properly stratified, the frequency of street cleaning practiced at the Central Ave. site results in an appreciable (48%) reduction of Fecal Coliforms; a marginal (15%) reduction of Total Coliforms; and essentially no reduction of Fecal Streptococci (Table 3-31). Because of the small data set which is finally obtained, results (especially magnitude of effect) should be taken with some caution. However, it is believed that the indications are correct.

The reasons the comparison was made with only Summer data (4 unswept; 5 swept events) are as follows:

a) There are seasonal differences for total coliform, fecal coliform and fecal streptococci.

b) For the street sweeping evaluation:

Winter data were not used because of the imbalance in observations, (10 vs 2) and also the imbalance in time (sweep data toward end of period).

Fall data were not used because of the imbalance in observations (5 vs 1).

Given the variability in the data, a good estimate of the mean cannot be made on the basis of only 1 or 2 samples. This left only the summer data, and while 4 and 5 observations are still quite small, they look consistent otherwise, and permit an initial evaluation.

Recognizing the seasonal differences, it would increase the confidence of the evaluation if more data had been collected during the summer period. However, as stated previously, the difficulty in forecasting summer storms, and the fact that summer storms are often of very short duration, precluded additional manual sampling events in the summer.

In summary, while the above evaluation indicates a possible significant removal of fecal coliforms by street cleaning during the summer, the value of street cleaning as a potential control measure is rather suspect. The management plans presented in Section 3.4 assume a 50 percent removal of total coliforms due to street cleaning, which, according to the statistical analysis performed, does not occur.

(b) Chemical Parameters

Tables 3-32 through 3-38 contain the storm loading data for the selected chemical parameters, TKN, NH_3-N, NO_3-N, No_2-N, total phosphorous, total suspended solids, and chloride, analyzed during the project. Analyses for heavy metals, BOD and COD were eliminated from the program after initial sampling events indicated that these parameters were either below detectable limits, or were found at insignificantly low levels.

Table 3-30

CENTRAL AVENUE SITE
STATISTICAL EVALUATION OF BACTERIAL EMCs and LOADS
(ALL DATA)

I. Without Intensive Street Cleaning

	Precip. (in.)	Runoff (Acre-ft.)	EMC (10³MPN/100ml) Total Coli	EMC (10³MPN/100ml) Fecal Coli	EMC (10³MPN/100ml) Fecal Strep	Load (10¹⁰ Organisms) Total Coli	Load (10¹⁰ Organisms) Fecal Coli	Load (10¹⁰ Organisms) Fecal Strep
Mean	0.45	0.839	123	15.8	43	118	15.	58
Median	0.36	0.483	14	3.2	19	8.1	1.85	11
Coef Var	0.75	1.42	8.74	4.79	2.02	14.55	8.04	5.18
Correlation Coef. Runoff Volume to EMC			−0.05	−0.06	0.18			

II. With Intensive Street Cleaning

	Precip. (in.)	Runoff (Acre-ft.)	EMC (10³MPN/100ml) Total Coli	EMC (10³MPN/100ml) Fecal Coli	EMC (10³MPN/100ml) Fecal Strep	Load (10¹⁰ Organisms) Total Coli	Load (10¹⁰ Organisms) Fecal Coli	Load (10¹⁰ Organisms) Fecal Strep
Mean	0.65	1.389	173	24.3	68.5	359	38.2	104
Median	0.49	0.856	67	13.6	48.7	69	14.0	50
Coef Var	0.86	1.28	2.37	1.49	0.99	5.10	2.55	1.84
Correlation Coef. Runoff Volume to EMC			+0.24	+0.05	0.00			

Most of the differences in load factors among the storm events appear to be due to the characteristics unique to each rainfall rather than to seasonal conditions or to the street cleaning. A notable exception is chloride which increased significantly following road salt application during the winter.

A statistical evaluation of TSS, TKN and TP further indicates that street sweeping, as shown on Table 3-39 and summarized on Table 3-40, does not reduce these parameters.

Similar results have been reported from other NURP street sweeping projects. One speculation is that sweeping action creates finer particle size for material not picked up, making it more susceptible to washoff (Driscoll, 1983).

Given the inherent variability from storm to storm for the sampling at Central Ave., it is not appropriate to conclude that sweeping causes an increase.

Table 3-31

CENTRAL AVENUE SITE
STATISTICAL EVALUATION OF BACTERIAL EMC REDUCTION DUE TO STREETSWEEPING — SUMMER DATA

Condition	Date	Volume (inch)	EMC (10^3MPN/100ml) TC	FC	FS
I. Without Intensive Street Cleaning	5-11-81	0.018	209	41.5	60.2
	6-2-81	0.039	240	93.4	53.3
	6-25-81	0.152	206	27.9	163
	7-28-81	0.053	124	31.1	17.1
II. With Intensive Street Cleaning	6-1-82	0.894	240	36.6	94
	6-16-82	0.036	88	14.5	75.5
	6-29-82	0.093	122	40.7	99.1
	8-9-82	0.170	234	15.4	45.7
	9-1-82	0.016	134	18.1	64.

	Total Coli			Fecal Coli			Fecal Strep			Runoff Volume (inch)	
	Without Sweeping	With Sweeping	% Reduction	Without Sweeping	With Sweeping	% Reduction	Without Sweeping	With Sweeping	% Reduction	Without Sweeping	With Sweeping
Mean	197	167	15%	49.7	25.6	48%	83.7	76.6	8.5%	0.07	0.28
Median	189	152	20%	42.8	22.7	47%	54.7	72.9	(-Neg)	0.05	0.14
Coef Var	0.30	0.46		0.59	0.52		1.16	0.32		1.09	1.74
Correlation Coef., Vol to EMC	−0.12	+0.88		−0.45	+0.54		+0.16	0.49			

Table 3-32

CENTRAL AVENUE SITE
TOTAL KJELDAHL NITROGEN: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	$\overline{\text{Load}}$ Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.260	1.252	0.887	0.023	0.0120	0.0240	20
12-09-80	0.16	0.063	0.945	0.130	—	0.0018	0.0111	24
02-02-81	0.57	0.632	2.259	3.690	0.0755	0.0506	0.8870	79
03-11-81	0.14	0.117	1.296	0.376	—	0.0052	0.0368	116
03-30-81	0.44	0.444	1.222	1.425	—	0.0195	0.0444	135
04-14-81	0.66	1.092	0.727	1.968	0.0598	0.0270	0.0409	150
05-11-81	0.19	0.111	1.621	0.423	—	0.0058	0.0172	14
06-02-81	0.31	0.235	1.262	0.801	0.0843	0.0110	0.0354	37
06-25-81	0.45	0.924	1.631	4.113	0.0918	0.0564	0.1252	8
07-28-81	0.22	0.320	1.935	1.756	0.0648	0.0240	0.1091	41
10-27-81	0.26	0.472	0.583	0.748	0.0450	0.0125	0.0394	16
12-01-81	0.55	0.832	0.749	1.694	0.2124	0.0232	0.0422	27
12-14-81	0.41	0.637	0.772	1.339	0.0372	0.0184	0.0448	80
02-03-82	1.15	5.750	0.575	8.988	0.0521	0.1231	0.1071	86
03-16-82	0.42	0.797	0.456	0.996	0.0480	0.0140	0.0330	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	$\overline{\text{Load}}$ Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	0.875	0.927	0.0500	0.0127	0.0510	0
04-26-82	0.93	1.670	0.438	2.150	0.0320	0.0210	0.0226	4
06-01-82	1.97	5.440	0.627	8.050	0.1339	0.1110	0.0560	5
06-16-82	0.18	0.219	5.200	3.130	0.0816	0.0430	0.2380	0
06-29-82	0.37	0.565	1.124	1.360	—	0.0190	0.0500	5
08-09-82	0.48	1.035	1.183	3.330	0.0330	0.0462	0.0951	4
09-01-82	0.44	0.644	0.968	1.696	0.0800	0.0232	0.0528	5
10-25-82	0.55	1.050	1.880	5.369	0.0548	0.0736	0.1337	4

Table 3-33

CENTRAL AVENUE SITE
NH_3—NITROGEN: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	0.229	0.147	0.016	0.0020	0.0040	20
12-09-80	0.16	0.063	0.163	0.022	—	0.0003	0.0019	24
02-02-81	0.57	0.632	0.591	1.006	0.027	0.0140	0.0250	79
03-11-81	0.14	0.117	0.434	0.122	0.008	0.0020	0.0120	116
03-30-81	0.44	0.444	0.424	0.502	0.056	0.0070	0.0160	135
04-14-81	0.66	1.092	0.222	0.600	0.030	0.0080	0.0130	150
05-11-81	0.19	0.111	0.432	0.112	0.018	0.0020	0.0080	14
06-02-81	0.31	0.235	0.124	0.078	0.016	0.0010	0.0030	37
06-25-81	0.45	0.924	0.312	0.787	0.047	0.0110	0.0240	8
07-28-81	0.22	0.320	0.703	0.638	0.036	0.0090	0.0400	41
10-27-81	0.26	0.472	0.085	0.110	0.011	0.0015	0.0058	57
12-01-81	0.55	0.832	0.225	0.510	0.430	0.0070	0.0130	16
12-14-81	0.41	0.637	0.234	0.406	0.014	0.0056	0.0140	27
02-03-82	1.15	5.750	0.147	2.300	0.016	0.0320	0.0270	80
03-16-82	0.92	0.797	0.190	0.413	0.017	0.0057	0.0135	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/ub)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	0.369	0.391	0.060	0.0054	0.0214	0
04-26-82	0.93	0.167	0.222	0.085	0.044	0.0149	0.0160	4
06-01-82	1.97	5.440	0.101	1.320	0.116	0.0178	0.0091	5
06-16-82	0.18	0.219	0.676	0.407	0.022	0.0058	0.0310	0
06-29-82	0.37	0.565	0.247	0.305	0.930	0.0042	0.0131	5
08-09-82	0.48	1.035	0.288	0.810	0.023	0.0110	0.0230	4
09-01-82	0.44	0.644	0.390	0.690	0.046	0.0094	0.0214	5
10-25-82	0.55	1.050	0.290	0.829	0.013	0.0114	0.0207	4

Table 3-34

CENTRAL AVENUE SITE
NO_3—NITROGEN: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	0.228	0.161	0.0120	0.0020	0.0040	20
12-09-80	0.16	0.063	0.973	0.133	—	0.0018	0.0114	24
02-02-81	0.57	0.632	0.579	0.987	0.0580	0.0140	0.0240	79
03-11-81	0.14	0.117	1.880	0.530	0.0160	0.0070	0.0520	116
03-30-81	0.44	0.444	0.529	0.626	0.0420	0.0090	0.0200	135
04-14-81	0.66	1.092	0.317	0.858	0.0270	0.0120	0.0180	150
05-11-81	0.19	0.111	0.661	0.171	0.0280	0.0023	0.0120	14
06-02-81	0.31	0.235	0.447	0.283	0.0290	0.0040	0.0030	37
06-25-81	0.45	0.924	0.757	1.907	0.0770	0.0260	0.0580	8
07-28-81	0.22	0.320	0.912	0.827	0.0470	0.0110	0.0500	41
10-27-81	0.26	0.472	0.036	0.048	0.0090	0.0007	0.0025	57
12-01-81	0.55	0.832	0.240	0.540	0.0300	0.0074	0.0135	16
12-14-81	0.41	0.637	0.432	0.750	0.0240	0.0100	0.0250	27
02-23-82	1.15	5.750	0.054	0.850	0.0052	0.0116	0.0100	80
03-16-82	0.42	0.797	0.220	0.477	0.0077	0.0070	0.0160	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	0.498	0.530	0.0003	0.0073	0.0290	0
04-26-82	0.93	1.670	0.126	0.634	0.0170	0.0087	0.0093	4
06-01-82	1.97	5.440	0.092	1.155	0.6500	0.0160	0.0080	5
06-16-82	0.18	0.219	0.910	0.548	1.4600	0.0075	0.0420	0
06-29-82	0.37	0.565	0.628	0.777	2.0800	0.0110	0.0290	5
08-09-82	0.48	1.035	0.550	1.550	0.0300	0.0210	0.0440	4
09-01-82	0.44	0.644	1.143	2.000	0.0900	0.0270	0.0620	5
10-25-82	0.55	1.050	0.208	0.549	0.0087	0.0082	0.0148	4

Table 3-35

CENTRAL AVENUE SITE
NO_2—NITROGEN: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.260	0.011	0.011	0.0010	0.0002	0.0003	20
12-09-80	0.16	0.063	0.030	0.004	—	0.0001	0.0004	24
02-02-81	0.57	0.632	0.048	0.079	0.0009	0.0011	0.0019	79
03-11-81	0.14	0.117	0.051	0.015	0.0010	0.0002	0.0015	116
03-30-81	0.44	0.444	0.027	0.031	—	0.0004	0.0010	135
04-14-81	0.66	0.192	0.011	0.030	0.0006	0.0004	0.0006	150
05-11-81	0.19	0.111	0.032	0.008	0.0004	0.0001	0.0006	14
06-02-81	0.31	0.235	0.027	0.017	0.0005	0.0002	0.0008	37
06-25-81	0.45	0.924	0.016	0.041	0.0005	0.0013	0.0004	8
07-28-81	0.22	0.320	0.016	0.515	0.0002	0.0002	0.0009	41
10-27-81	0.26	0.472	0.010	0.013	0.0006	0.0001	0.0006	57
12-01-81	0.55	0.832	0.030	0.070	0.0053	0.0009	0.0017	16
12-14-81	0.41	0.637	0.037	0.065	0.0012	0.0009	0.0022	27
02-03-82	1.15	5.750	0.011	0.175	0.0016	0.0024	0.0021	80
03-16-82	0.42	0.797	0.090	0.195	0.0011	0.0027	0.0064	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	0.030	0.032	0.0220	0.0004	0.0020	0
04-26-82	0.93	1.670	0.010	0.049	0.0085	0.0007	0.0007	4
06-01-82	1.97	5.440	0.008	0.103	0.0580	0.0014	0.0007	5
06-16-82	0.18	0.219	0.040	0.024	0.0300	0.0003	0.0018	0
06-29-82	0.37	0.565	0.040	0.049	0.0310	0.0007	0.0018	5
08-09-82	0.48	1.035	0.022	0.063	0.0003	0.0008	0.0018	4
09-01-82	0.44	0.644	0.022	0.038	0.0003	0.0005	0.0012	5
10-25-82	0.55	1.050	0.017	0.050	0.0009	0.0007	0.0013	4

Table 3-36

CENTRAL AVENUE SITE
TOTAL PHOSPHORUS: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	0.287	0.191	0.0030	0.0030	0.0060	20
12-09-80	0.16	0.063	0.173	0.024	—	0.0003	0.0021	24
02-02-81	0.57	0.632	0.372	0.633	0.0150	0.0090	0.0150	79
03-11-81	0.14	0.117	0.094	0.027	—	0.0004	0.0030	116
03-30-81	0.44	0.444	0.179	0.212	0.0810	0.0030	0.0070	135
04-14-81	0.66	1.092	0.157	0.424	0.0010	0.0060	0.0090	150
05-11-81	0.19	0.111	0.248	0.064	—	0.0010	0.0050	14
06-02-81	0.31	0.235	0.217	0.138	0.0030	0.0020	0.0060	37
06-25-81	0.45	0.924	0.313	0.790	0.0020	0.0110	0.0240	8
07-28-81	0.22	0.320	0.257	0.234	0.0020	0.0030	0.0140	41
10-27-81	0.26	0.472	0.138	0.180	0.0018	0.0025	0.0096	57
12-01-81	0.55	0.832	0.080	0.181	0.0058	0.0025	0.0045	16
12-14-81	0.41	0.637	0.386	0.669	0.0007	0.0092	0.0224	27
02-03-82	1.15	5.750	0.127	1.997	0.0021	0.0270	0.0240	80
03-16-82	0.42	0.797	0.084	0.182	0.0025	0.0025	0.0059	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	0.401	0.426	—	0.0058	0.0233	0
04-26-82	0.93	1.670	0.140	0.680	0.0032	0.0094	0.0100	4
06-01-82	1.97	5.440	0.114	1.460	0.4560	0.0200	0.0100	5
06-15-82	0.18	0.219	0.270	0.163	0.1670	0.0022	0.0124	0
06-29-82	0.37	0.565	0.267	0.333	—	0.0046	0.0120	5
08-09-82	0.48	1.035	0.387	1.090	0.0022	0.0150	0.0310	4
09-01-82	0.44	0.644	0.148	0.260	0.0043	0.0036	0.0081	5
10-25-82	0.55	1.050	0.291	0.832	0.0023	0.0114	0.0207	4

Table 3-37

CENTRAL AVENUE SITE
CHLORIDE: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	4.57	3.24	0.149	0.044	0.088	20
12-09-80	0.16	0.063	2.47	0.33	—	0.004	0.029	24
02-02-81	0.57	0.632	102.94	168.34	—	2.306	4.045	79
03-11-81	0.14	0.117	20.70	6.00	0.145	0.082	0.587	116
03-30-81	0.44	0.444	5.31	6.19	0.140	0.084	0.192	135
04-14-81	0.66	1.092	5.54	1.50	0.540	0.020	0.311	150
05-11-81	0.19	0.111	14.73	3.84	0.357	0.052	0.277	14
06-02-81	0.31	0.235	13.94	8.84	—	0.121	0.391	37
06-25-81	0.45	0.924	1.75	4.43	0.179	0.060	0.135	8
07-28-81	0.22	0.320	5.95	5.42	—	0.074	0.337	41
10-23-81	0.97	1.416	3.39	3.26	—	0.181	0.187	53
10-27-81	0.26	0.472	2.76	3.54	0.084	0.048	0.186	57
11-06-81	0.52	0.666	5.77	10.46	0.176	0.142	0.275	67
11-20-81	0.48	0.988	1.66	4.48	0.141	0.061	0.127	5
12-01-81	0.55	0.832	1.60	3.62	0.430	0.049	0.090	16
12-14-81	0.41	0.637	31.65	54.85	0.055	0.751	1.832	27
02-03-82	1.15	5.750	5.48	12.09	0.286	0.165	0.144	80
02-09-82	0.12	0.189	53.55	27.54	0.006	0.377	3.144	86
03-16-82	0.42	0.797	2.09	4.54	0.065	0.062	0.148	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Wetfall (lbs/ac)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	6.65	7.05	—	0.096	0.386	0
04-26-82	0.93	1.670	4.30	20.99	—	0.287	0.309	4
06-01-82	1.97	5.440	1.11	14.30	—	0.195	0.099	5
06-16-82	0.18	0.219	16.07	9.67	—	0.132	0.736	0
06-29-82	0.37	0.565	3.08	3.79	0.067	0.052	0.140	5
08-09-82	0.48	1.035	6.87	15.15	0.007	0.264	0.551	4
09-01-82	0.44	0.644	5.29	9.27	0.026	0.127	0.288	5
10-25-82	0.55	1.050	4.65	13.29	0.324	0.182	0.331	4

Table 3-38

CENTRAL AVENUE SITE
TOTAL SUSPENDED SOLIDS: EMC, LOAD AND LOAD FACTORS

I. Without Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
11-18-80	0.50	0.283	—	—	—	—	20
12-09-80	0.16	0.063	—	—	—	—	24
02-02-81	0.57	0.632	106.0	179.9	2.465	4.325	79
03-11-81	0.14	0.117	11.7	3.2	0.045	0.322	116
03-30-81	0.44	0.444	23.4	3.3	0.390	0.728	135
04-14-81	0.66	1.092	47.2	127.5	1.747	2.647	150
05-11-81	0.19	0.111	26.2	6.7	0.093	0.490	14
06-02-81	0.31	0.235	15.8	10.0	0.137	0.442	37
06-25-81	0.45	0.924	94.2	237.5	3.254	7.230	8
07-28-81	0.22	0.320	76.5	69.4	0.951	4.322	41
12-01-81	0.55	0.832	9.3	21.0	0.288	0.524	16
12-14-81	0.41	0.637	21.3	36.9	0.505	1.230	27
02-03-82	1.15	5.750	26.9	421.5	5.800	5.020	80
02-09-82	0.12	0.189	19.4	9.9	0.137	1.140	86
03-16-82	0.42	0.797	15.2	32.9	0.450	1.070	121

II. With Intensive Street Cleaning

Date	Precip.	Runoff (Acre-ft.)	EMC (mg/l)	Total Load (lbs)	Unit Load (lbs/ac)	Load Factor (lbs/ac/in)	Time Since Last Street Cleaning (Days)
03-31-82	0.25	0.368	55.0	55.2	0.760	3.030	0
04-26-82	0.93	1.670	33.2	162.0	2.220	2.390	4
06-01-82	1.97	5.440	15.6	200.2	2.740	1.390	5
06-16-82	0.18	0.219	29.0	17.4	0.240	1.330	0
06-29-82	0.37	0.565	45.7	56.3	0.772	2.090	5
08-09-82	0.48	1.035	187.7	528.1	7.230	15.100	4
09-01-82	0.44	0.644	31.8	54.9	0.750	1.710	5
10-25-82	0.55	1.050	43.6	124.4	1.705	3.100	4

Table 3-39

CENTRAL AVENUE SITE
STATISTICAL EVALUATION OF TSS, TKN, TP — EMC's and LOADS

I. Without Intensive Street Cleaning

	PRECIP.	RUNOFF (Acre-ft.)	TSS EMC (mg/l)	TKN EMC (mg/l)	TP EMC (mg/l)	TSS Load (Lbs)	TKN Load (Lbs)	TP Load (Lbs)
Mean	0.43	0.794	38.2	1.17	0.211	118.2	2.082	0.445
Median	0.35	0.420	28.0	1.04	0.184	31.6	1.207	0.214
Coef Var.	0.71	1.60	0.93	0.51	0.55	3.6	1.41	1.82
Correlation Coef.								
Runoff Volume to EMC			+0.22	−0.27	+0.24			

II. With Intensive Street Cleaning

	PRECIP.	RUNOFF (Acre-ft.)	TSS EMC (mg/l)	TKN EMC (mg/l)	TP EMC (mg/l)	TSS Load (Lbs)	TKN Load (Lbs)	TP Load (Lbs)
Mean	0.65	1.389	54.3	1.52	0.258	162.5	3.36	0.692
Median	0.49	0.856	42.1	1.15	0.230	94.5	2.60	0.521
Coef Var.	0.86	1.28	0.82	0.87	0.51	1.40	0.82	0.87
Correlation Coef.								
Runoff Volume to EMC			−0.28	−0.67	−0.64			

Table 3-40

CENTRAL AVENUE SITE
STREET CLEANING COMPARISON
(All Data)

	Without Sweeping	With Sweeping
Runoff Vol (Acre ft.)	0.79	1.39
TSS Conc (mg/l)	38.0	54.0
Load (lbs)	118.0	162.0
Corr Coef Vol/Conc.	+ 0.22	− 0.28
TKN Conc (mg/l)	1.17	1.52
Load (lbs)	2.08	3.36
Corr Coef.	− 0.27	− 0.67
TP Conc (mg/l)	0.211	0.258
Load (lbs)	0.45	0.69
Corr Coef	+ 0.24	− 0.64
No. of observations	15	8

Note: Values Tabulated are Mean Values estimated from Log Normal Distribution

3.4 THE MODELING EFFORT

3.4.1 Receiving Water Modeling. A complete report of the mathematical modeling of the South Shore-Great South Bays which took place during this study is presented in Appendix F. This section consists of a summary including excerpts from that report.

One of the tasks in the NURP study was to determine the reduction in coliform loadings to the bays necessary to certify lands currently closed to the taking of shellfish.

Digital link-node water quality models (Tetra Tech, 1977) were developed during the Long Island "208" study to predict the receiving water quality of the area. The Tetra-Tech numerical models represent the estuarine systems as variable grid networks of *nodes* and *channels links.* Nodes are discrete waterbody units, charcterized by surface area, depth, side slope and volume. The nodes are interconnected by channels, each having an associated length, width, cross-sectional area, hydraulic radius, side slope and friction factor. Water is constrained to flow from one node to another through these defined channels, advecting and diffusing water quality constituents between nodes. The following are underlying assumptions of the estuary model:

- The estuarine system is well mixed vertically.
- The law of conservation of mass is obeyed for water quality constituents.
- Chemical reaction rates may be estimated using first order kinetics characterized by reaction-specific rate coefficients.

In the case of the Long Island NURP, this meant that an accurate approximation of coliform decay rates was necessary.

The estuary model is composed of three separate components — a *hydrodynamic* model, a *tidally averaged (steady state) quality* model, and a *dynamic quality* model. The hydrodynamic and quality models are used in sequence so that the results of one become input for the next.

Both quality models can be used to simulate any combination of the following nine parameters and have the capability to include up to four additional user-specified constituents:

1. Salinity
2. Total Nitrogen
3. Total Phosphorus
4. Total Coliform Bacteria
5. Fecal Coliform Bacteria
6. Carbonaceous BOD
7. Nitrogenous BOD
8. Dissolved Oxygen
9. Temperature

The use of these models requires considerable information about point and non-point inputs as well as the hydrodynamics of the receiving water. The information requirements are extensive, and the costs incurred for running any of these models are relatively great, increasing as one proceeds from the steady state to the dynamic or time varying model.

It was possible to develop a simpler and less costly model, called the *Matrix Manipulation Model* (MMM), because of the assumed linearity of the bay system, as reflected in the mathematical equations which describe it. The model operates upon either actual or synthetically generated rainfall data covering extended periods of up to one year and produces statistical analyses of receiving water coliform concentrations. The response within each node of the "208" water quality model to separate unit inputs, including those at the boundary, also had to be incorporated into MMM. This was done by generating runoff-related bacteriological loads to 35 shoreline nodes based upon a large (2 inch) storm.

The model evaluated the responses within 90 nodes covering the South Shore Bays in Nassau County and the Great South Bay system eastward to the Carmans River in Suffolk. Because of the assumed linearity of the bay system, the response within any given node is directly proportional to the magnitude of the input which causes that response. For example, the doubling of an input results in the doubling of the response. Furthermore, the response within a given node is equal to the sum of the responses caused by each individual input.

The Matrix Manipulation Model also generates rainfall events and associated runoff-related bacteriological loadings by using the statistical properties of Long Island rainfall, together with a total coliform loading factor (6.2 $\times$ 10^{10}MPN/acre inch of rainfall). This loading estimate was developed from the analysis of runoff from medium density residential land during the "208" study. It is reasonably consistent with, but somewhat greater than that obtained during the NURP study. The model then calculates the coliform concentrations in the receiving waters and determines whether or not the water quality meets New York State Department of Environmental Conservation bacteriological standards for designation as certified shellfish lands. By selectively reducing runoff loads until the receiving waters meet these standards, the level of required control measure effectiveness can be determined.

3.4.2 Use of the Matrix Manipulation Model. Before the model was used to evaluate the effectiveness of various control measures in securing additional openings of receiving waters currently closed to the taking of shellfish, it was first necessary to subject it to a number of tests. The first of these involved comparing predicted results with actual receiving water total coliform data collected over a 12-month period. Actual rainfall data were used to generate the coliform loadings to the bay. No allowance was made for any attenuation of loads on the landscape. The model results and the receiving water data were in excellent agreement.

It was also necessary to compare the effect of using different random storm sequences having the same annual rainfall upon the degree of load reduction needed to redesignate the shellfish lands as certified. This was done for a series of 11 storm sequences, and an assumption of 95 percent reduction of all storm loads. The results were found to be highly consistent; that is, for four of the five nodes whose response was investigated, each node consistently either met or failed to meet NYSDEC bacteriological standards for all storm sequences. The one node which fluctuated was on the borderline in terms of the standards and would be expected to sometimes meet and sometimes fail to meet them due to the variations in the nodal response associated with the storm sequences.

Finally, the effect of the total amount of yearly rainfall upon the opening or closing of the shellfish beds was investigated. The model was run for two annual rainfall volumes (45.9 inches and 51.3 inches) and two assumed coliform load reductions (zero and 95 percent). It was found that the amount of rainfall made no difference, in terms of the designation of the shellfish lands within the five selected notes, for a given assumed load reduction. This is due to the fact that NYSDEC regulations only consider coliform concentrations following selected rainfall events. Four of the five nodes, which were originally predicted to be uncertified under an assumption of no load reduction, did however attain certified status under the assumption of 95 percent load reduction for both rainfall conditions.

Water quality improvements were measured in terms of the reopening of closed shellfish beds, i.e. redesignating previously uncertified shellfish lands as certified. Therefore, it was necessary to incorporate the standards used by NYSDEC in assessing the suitability of waters into the MMM. NYSDEC has determined that worst pollution conditions (WPC) occur on the day of, and dur-

ing the two days following, a rainfall equal to or greater than 0.25 inches within a 24-hour period. Following the determination of WPC, NYSDEC applies either of two standards to samples collected only during WPC in areas being used for or considered for shellfishing. Prior to 1982, total coliform were primarily considered by the State in making its assessments. Now, if the standard can be met for either total or fecal coliform results, the receiving water may remain open or be considered for opening for the taking of shellfish. The first standard requires that 50 percent or more of the results obtained from samples taken during WPC must have total coliform concentrations equal to or less than 70 MPN/100 ml, and that no more than 10 percent of the results exceed total coliform concentrations of 230 MPN/100 ml or 330 MPN/100 ml, depending upon the number of fermentation tubes used for each dilution when performing the laboratory analysis. The second standard requires that 50 percent or more of the results obtained from samples taken during WPC must have fecal coliform concentrations equal to or less than 14 MPN/100 ml, and that no more than 10 percent of the results exceed fecal coliform concentrations of 43 MPN/100 ml or 49 MPN/100 ml, again depending on laboratory procedures, as previously noted.

If the standard is met for either total or fecal coliforms, the area is considered bacteriologically satisfactory for shellfishing. For the NURP modeling evaluation, the total coliform concentration of 230 MPN/100 ml (more restrictive than the 330 MPN/100 ml value) was applied in determining whether this part of the total coliform standard had been met.

The coliform die-off rate that was used in this study was based on a statistical analysis of in-situ NYSDEC data (Redman, 1979) and is much lower than the reported seawater values (Mitchell and Chamberlin 1978). Since the total coliform die-off rate was estimated based upon bay water samples and the model was successfully verified using total coliform data, it was deemed more reliable to use total coliforms in this study. No corresponding field estimates of fecal coliform die-off rates were available.

3.4.3 Load Reduction Analysis

3.4.3.1 Stream and Overland Runoff. As mentioned previously, the main purpose for developing and applying the MMM to the South Shore-Great South Bays was to determine the reductions of total coliform loadings contributed by urban runoff needed to reopen shellfish lands currently uncertified for the taking of shellfish. A total of approximately 19,000 acres, comprising 11,000 in Nassau and 8,000 in Suffolk, are currently uncertified.

In the Nassau-Suffolk area, there are two types of urban runoff that must be considered — stream and overland. Stream runoff is defined as that which drains into the freshwater streams and is then transported to the bays. Overland runoff is that which drains directly or via storm sewers to the bays or tidal portions of the streams. This distinction is made because these two types of runoff may require substantially different measures for the control of bacteria. Overland runoff control is generally limited to dog fecal waste control ordinances, street sweeping or leaching facilities. Stream runoff may be controlled by making better use of ponds and stream corridors, as well as of the above measures.

Nassau County has approximately 51,300 acres that drain to the South Shore Bays. Of this, about 30,800 acres or 60 percent, drain through freshwater stream corridors and the runoff from the remaining 20,500 acres enters the bays via overland drainage. Much of the overland flow in Nassau originates in the western bay areas and from the Long Beach barrier island. Suffolk has a total of approximately 32,100 acres that drain to Great South Bay of which 24,400 acres or 76 percent are drained via stream corridors while the remaining 7,700 acres contribute overland runoff.

3.4.3.2 Equal Load Reductions. The model predicted that almost all the closed shellfish lands on Long Island's South Shore would reopen following an overall reduction of 90 to 95 percent of the stream and overland runoff total coliform loads. Because the stream and overland runoff require control measures having different removal efficiencies, the effect of various combinations of 0, 50, 75, and 95 percent total coliform reductions for both stream and overland runoff were evaluated. The results of these runs are presented in Table 3-41 as reopened acreages of shellfish lands for different combinations of stream and overland runoff control. Examination of this table reveals a very significant trend. In order to obtain any great benefit from controlling coliform in overland flow, stream reductions must be on the order of 95 percent.

A series of model runs was also made using design storms ranging from 0.3 to 2.0 inches and overall load reductions of 95 percent. Applying the existing NYSDEC standards, the model results showed that controlling storms up to 1.25 inches yielded the same results in terms of shellfish bed openings as controlling all storms at a 95 percent load reduction. When the annual loading to the bays was reduced by 95 percent, the model predicted that at least 90 percent of the closed shellfish beds would be opened, regardless of storm size.

3.4.3.3 Site-Specific Controls. Due to the high degree of mixing and flushing in the South Shore bays of Nassau County, it is almost impossible to obtain an improvement in a specific area, unless there are load reductions in a much more extensive area. In Suffolk County, for western Great South Bay, there is not as much tidal action in the nearshore areas, so it is possible to obtain site-specific reductions. Refer to the figures in Appendix D to determine what percent reduction is needed on a number of the stream basins in order to reopen the shellfish beds.

To better resolve the effects of site-specific control measures, Nassau was broken into two areas, west and east. Two model runs were performed, assuming 75 percent overland runoff control in one area and none in the other. Stream control was kept at 95 percent in both west and east. For overland control only in the west, 46 percent of the closed beds reopen in Nassau — 71

Table 3-41

SHELLFISH OPENINGS FOR CONTRIBUTIONS OF LOAD REDUCTIONS

PERCENT OF STREAM RUNOFF CONTROLLED	REOPENED SHELLFISH BEDS (ACRES) PERCENT OF OVERLAND RUNOFF CONTROLLED				
	0	50	75	95	
0	0	0	0	0	Suffolk (S)
	0	922	1994	3339	Nassau (N)
	0	922	1994	3339	Total (T)
50	0	0	0	582	S
	996	3038	4010	4309	N
	996	3038	4010	4891	T
75	582	1105	1105	1105	S
	1642	3361	4359	5557	N
	2224	4466	5464	6662	T
95	1105	2351	6328	6328	S
	1966	3860	7150	11061	N
	3071	6211	13478	17389	T

Adjusted from total closed acreage

Total closed in Nassau: 11,157 acres
Total closed in Suffolk: 8,010 acres
Source: Lawler, Matusky and Skelly, 1982

percent in the west zone and 26 percent in the east. There are about 6200 and 5000 closed in the east and west, respectively. For overland control only in the east, about 55 percent of the closed beds reopen — 7 percent in the west zone and 93 percent in the east. However, there is much more overland area to control in the west than in the east, so it appears that initial control measures should be located in eastern Nassau.

3.4.4 Alternative Plans. In order to obtain estimates of the potential costs of controlling stormwater runoff into the South Shore Bays of Nassau County and the Great South Bay of Suffolk County, the engineering consultant was requested to formulate a number of alternative plans, including a no-action alternative. Since this planning was performed early in the study, subsequent analysis has indicated that some assumed efficiencies for the control measures included in the alternatives were overly optimistic. However, the costs developed do offer a point of departure for future discussions of implementation. The plans cover varying levels of effort and expenditure ranging from Plan 1, the minimal action alternative, in which the only proposed control is infiltration through the upland reaches of certain streams, which are expected to dry as a result of sewering, to Plan 5, in which all feasible control measures are implemented for all streams and leaching catch basins and dog clean up ordinances are used to effect a 75 percent reduction of the coliform loading attributable to overland runoff.

The assumed reductions in coliform discharges brought about by each alternative were then entered into the MMM, in order to determine the nodes that thereby became certifiable for shellfishing. It was found that, in some cases, control measures in a particular node did not bring sufficient improvement to reopen that node, and that these control measures could be eliminated without adversely affecting other, reopened, nodes. In this way, costs could be kept to a minimum.

Table 3-42 summarizes the main features of each alternative, and the nodes and acres of shellfishing beds that the model determined would be reopened. Costs are discussed in Section 5.1.2, and are summarized in Table 5-2.

3.5 THE SALMONELLA STUDY

3.5.1. Introduction The use of coliform bacteria, both total and fecal, as indicators of fecal pollution derived from humans and other warm-blooded animals is an established and accepted measure for determining the sanitary quality of fresh and saline surface waters. Ideally, indicator bacteria will be encountered only where pathogenic bacterial strains associated with fecal matter may be present. Numerous researchers have investigated the relationship between the presence of pathogenic bacteria and densities of indicator organisms, and have reported conflicting findings (Bott, 1973; Kenner & Clark, 1974).

In some instances, little or no correlation between levels of total or fecal coliform bacteria and the presence of pathogens, i.e. *Salmonella*, was determined. In other instances, primarily those related to sanitary sewage and freshwater receiving waters associated with sanitary sewage discharges, certain concentrations of indicator bacteria were found to be associated with pathogen presence. Investigations of indicator/pathogen relationships in stormwater runoff and estuarine receiving waters have also produced conflicting findings. (Olivieri et al., 1977; Geldreich, 1978).

The NURP Technical Advisory Committee perceived the need to attempt the further evaluation of the historically assumed relationship between the presence of indicator bacteria in the environment and that of bacteria pathogenic to humans.

In February, 1980, the LIRPB convened a group of experts drawn from the County Health Departments, NYSDEC, U.S. Geological Survey, various branches of the USEPA, and USFDA and the Long Island 208 Study virus consultant. A consensus of those present supported the selection of Salmonella as the pathogen to be investigated.

Table 3-42

SUMMARY OF MAJOR COMPONENTS OF PLAN ALTERNATIVES[1]

Control Measure Plans	SHELLFISH AREAS OPENED NASSAU (11,157 acres closed) # Acres	% Total	Nodes Opened	SUFFOLK (8,010 acres closed) # Acres	% Total	Nodes Opened
1. Minimal Action—Increase infiltration in dry stream beds	996	9	24,27,32	0	0	—
2. Plan 1 plus Stream Control from Bellmore Ck east	1642	15	24,27,32 35,39	1105	14	77,79
3. Plan 2 plus increased control in Seamans, Seaford, Carmans, Santapogue, and Carll's River	1642	15	same as #2	1105	14	same as #2
4. Plan 3 with 50% overland control east of Bellmore Creek (Once/week street sweeping and dog ordinances in overland area).[a]	1642	15	same as #2	2351	29	55,77,79
5. All Streams controlled plus overland control throughout (Leaching catch basins in overland area)[b]	6873	62	5,6,20,22, 40,41 2,3,4,7,12,13 15,16,24,25, 27,30,32,35, 39	4519	56	52,55,76,77, 79

[a] No added benefit in Nassau County due to overland control (Model assumes 50% removal).

[b] Questionable implementability; depth to groundwater south of Merrick Road and Montauk Highway assumed to be greater than 5 ft.

[1] From Lawler, Matusky and Skelly, 1982.

Preliminary efforts concentrated on refining Salmonella isolation methodology and conducting various Salmonella recovery and survival experiments (Appendix H). Routine testing of environmental samples for the presence of Salmonella by a GF/F filtration/elution MPN technique extended from March through December 1982. During that time, 393 samples were analyzed. Table 3-43 provides a summary of the number and source of samples and analytical findings for six categories of sample source. Each sample source category comprises a number of individual locations within the bi-county region that were chosen because of an assumed potential for yielding Salmonella. Determinations of this potential were based upon factors at each site believed to favor the presence of pathogens, such as large waterfowl populations, drainage area characteristics, and past histories of illegal sanitary discharges. Each source category was composed of the following numbers of sites:

Sewage–five water pollution control facilities located in Nassau.
Storm Runoff–three sites in Nassau and one in Suffolk.
Ponds–twelve sites in Nassau and three in Suffolk.
Streams–three sites in Nassau and four in Suffolk.
Estuarine–twelve locations in Nassau waters.
Sediments–six Nassau pond sites.

3.5.2. Findings. Sewage samples from five water pollution control facilities, including samples of influent, non-chlorinated effluent and sludge, had the highest Salmonella-positive rate, 73 percent. The geometric mean density for these samples was 16 MPN/100 ml with five Salmonella serogroups represented. Storm runoff samples were taken primarily from medium density residential drainage areas. These included samples collected at storm

Table 3-43

SALMONELLA STUDY

Summary of Positive Isolations March–December 1982

Sample Source	Sampling Sites	Sample Total	Salmonella Positive Samples	Percent Salmonella Positive	Mean MPN/100 ml	Serological Groups (s)
Sanitary Sewage	5	22	16	73	16.0	B,C_1,C_2,D,E
Storm Runoff	4	40	13	33	0.048	B,C_2
Pond Effluent	15	199	21	11	0.073	B,C_2,E
Streams	7	84	4	5	0.045	B,C_2
Estuarine	12	39	1	3	0.091	B
Sediments	6	9	0	0	—	—
STUDY TOTALS	49	393	55	14	—	—

drainage system effluent discharges (Central Ave., Deer Park) and runoff conveyed in freshwater stream channels (Unqua River, Massapequa). Storm event samples were 33 percent positive for Salmonella, with a mean value of 0.048 MPN/100 ml, and with two serogroups detected. Surface water samples from ponds, streams and estuarine sites ranged from 3 to 11 percent positive for Salmonella, with mean values between 0.045 and 0.091 MPN/100 ml. A limited number of sediment samples were examined with negative results. The sites chosen for collection of sediment samples were primarily ponds where Salmonella had been isolated from effluent water samples. Fourteen percent of samples from all sources in this study were positive for Salmonella, with isolates made in five serogroups: B, C_1, C_2, D and E. Salmonella belonging to Serogroup B, the most frequently isolated serogroup, were present in 75 percent of all positive samples.

Much of the early literature pertaining to Salmonella isolation in the environment reported qualitative findings, i.e., whether or not the pathogen was isolated. More recently, quantitative MPN data have been presented.

Table 3-44 lists the concentrations of Salmonella found in samples from the various sites evaluated in this study and compares them with the findings of other investigators. The original table as published by Olivieri et al. presented all data as MPN/10 liters for ease of comparison. The Salmonella concentrations detected in sewage during this study are very similar of those found by other investigators as cited in Olivieri et al. (1977). However, their ranges for Salmonella in surface waters and stormwater runoff are considerably broader than those found in this study, where values at the low end of previously reported ranges predominated (see Table 3-44).

In a 1977 USEPA document, *Microorganisms in Urban Stormwater*, Olivieri, et al., related the frequency of Salmonella detection to the varying concentration levels of fecal coliform bacteria for an array of sample sources. An equivalent approach is used in Table 3-45 to compare the frequency of detection of Salmonella in sewage, stormwater, pond effluent, stream and estuarine samples, with varying ranges of fecal coliform MPN values. A summary for all surface water samples, excluding sewage samples, is also provided. Table 3-46 presents the comparison between Salmonella isolates and total coliform levels, and Table 3-47 compares detection of Salmonella with that of fecal streptococci.

A direct relationship between elevated densities of each of the indicator bacterial groups and Salmonella isolations is evident in raw sewage and in the effluent from secondary treatment facilities. Salmonella isolates are associated with total and fecal coliform densities greater than 20,000 MPN/100 ml, and with fecal streptococci densities greater than 2,000 MPN/100 ml. Low levels of indicators were generally not detected. These findings are in agreement with data from the literature (Olivieri et al. 1977; Geldreich, 1978).

Thirty-three percent of runoff samples were positive for Salmonella. These Salmonella isolates in stormwater runoff samples were obtained at all detected levels of indicator bacteria except the < 200 MPN/100 ml range. Salmonella densities ranged from 0.030 to 0.230 MPN/100 ml, with a mean of 0.048 MPN/100 ml.

Table 3-44

COMPARISON OF THE LEVELS OF SALMONELLA FOUND IN SURFACE WATER AND SEWAGE[1]

Source of Sample	Number of Samples	Range of Salmonella MPN/10 liters	References
Sewage	3	20,000	Kampelmacher and Van Noorle Jansen, 1970[2]
Sewage	8	11,000 to 1,100,000	Cheng et al, 1971[2]
Sewage	17	700 to 25,000	Phirke, 1974[2]
Sewage	15	< 300 to 150,000	Kenner and Clark, 1974
Sewage	34	3 to > 27,000	Olivieri et al, 1977
River	8	150 to > 30,000	Kenner and Clark, 1974
Creek	2	450 to 1,200	Kenner and Clark, 1974
Urban Stream	94	< 0.9 to 320	Olivieri et al, 1977
Storm Runoff	2	20 to 150	Kenner and Clark, 1974
Storm Runoff	140	< 0.9 to > 11,000	Olivieri et al, 1977
Sewage	22	360 to 24,000	L.I. NURP Salmonella Study
Ponds	199	3 to 122	L.I. NURP Salmonella Study
Streams	84	3.6 to 9	L.I. NURP Salmonella Study
Estuarine	39	9.1	L.I. NURP Salmonella Study
Storm Runoff	40	3 to 23	L.I. NURP Salmonella Study

[1] After Olivieri et al., 1977.
[2] Discussed in Olivieri et al., 1977.

Dry-weather stream samples were obtained from six different freshwater systems. Two of the four positive findings from a total of 84 samples occurred in replicate samples from one stream. The mean Salmonella concentration for stream samples, was 0.045 MPN/100 ml. Pond effluent samples, generally representing dry-weather baseflow conditions, comprised the largest group of water samples collected. Of the 199 samples collected at fourteen ponds, twenty-one (11 percent) were positive for Salmonella. Values ranged from 0.03 to 1.2 MPN/100 ml, with a mean of 0.073 MPN/100 ml. The majority of Salmonella positive samples, 15 out of 21, were obtained from the effluent waters of three ponds. Effluent to tidal water from Argyle Lake, the final impoundment along the Carlls River, provided the highest occurrence rate, 50 percent (five of ten samples). Milburn Pond had a 19 percent incidence rate of Salmonella (six of thirty-one samples). Unqua Pond effluent to tidal water had a 14 percent incidence rate (four of twenty-nine samples).

It was hypothesized that wild and semi-wild ducks, Canada geese and/or seagulls constituted the source or sources of the observed Salmonella in pond

effluent. However, while the three aforenoted ponds do have considerable resident waterfowl populations, presumably supported by public feeding, other ponds with equal or much higher concentrations of waterfowl, likewise fed by the public, either exhibit very low percentages of Salmonella isolations or have been found to be negative for Salmonella.

Estuarine samples, of which thirty-nine were obtained, generally exhibited lower levels of indicator bacteria. No less than 84 percent of the samples had indicator densities of 2,000 MPN/100 ml or less. One sample, collected in a tidal creek, was found to be positive for Salmonella (0.091 MPN/100 ml), and had corresponding total coliform, fecal coliform and fecal streptococcal densities of 93, 93 and 2,400 MPN/100 ml, respectively.

A complete discussion of findings and their evaluation, including speciation of Salmonella isolates, will be presented in a seperate report now in preparation.

Table 3-45

COMPARISON OF THE FREQUENCY OF DETECTION OF SALMONELLA WITH LEVELS OF FECAL COLIFORMS

	Fecal Coliforms		Salmonella	
Sample Source	Range MPN/100 ml	No. of Samples In Range	Number Positive	% Positive Findings
Sewage	0-200	1	0	0
	201-2,000	1	0	0
	2,001-20,000	0	0	0
	> 20,000	14	12	86
	(a)	6	4	
Storm Water Runoff	0-200	1	0	0
	201-2,000	12	5	42
	2,001-20,000	17	5	29
	> 20,000	10	3	30
Pond Effluents	0-200	75	2	3
	201-2,000	67	9	13
	2,001-20,000	36	3	8
	> 20,000	8	2	25
	(a)	13	5	
Streams	0-200	15	1	7
	201-2,000	36	1	3
	2,001-20,000	29	1	4
	> 20,000	4	1	25
Estuarine	0-200	23	1	4
	201-2,000	11	0	0
	2,001-20,000	4	0	0
	> 20,000	0	0	0
	(a)	1	0	
Sediments	(a)	9	0	0
All Surface Sites (excluding sanitary sewage)	0-200	114	4	4
	201-2,000	126	15	12
	2,001-20,000	86	9	10
	> 20,000	22	6	27
	(a)	23	5	
TOTAL		371	39	11
Olivieri, et al BALTIMORE STUDY				
Overall Total (b)	0-200	18	5	28
	201-2,000	46	41	89
	> 2,000	210	202	96

(a) Early samples, sediments and sludges – not tested
(b) Raw Sewage, 32; urban streams, 92; upland reservoir, 14; storm runoff, 136.

Table 3-46

COMPARISON OF THE FREQUENCY OF DETECTION OF SALMONELLA WITH LEVELS OF TOTAL COLIFORMS

	Total Coliforms		Salmonella	
Sample Source	Range MPN/100 ml	No. of Samples In Range	Number Positive	% Positive Findings
Sewage	0-200	0	0	0
	201-2,000	0	0	0
	2,001-20,000	0	0	0
	> 20,000	16	12	75
	(a)	6	4	
Storm Water Runoff	0-200	0	0	0
	201-2,000	4	2	50
	2,001-20,000	9	4	44
	> 20,000	27	7	26
Pond Effluents	0-200	29	1	3
	201-2,000	74	2	3
	2,001-20,000	60	9	15
	> 20,000	23	4	17
	(a)	13	5	
Streams	0-200	8	1	13
	201-2,000	17	0	0
	2,001-20,000	38	2	5
	> 20,000	21	1	5
Estuarine	0-200	16	1	6
	201-2,000	16	0	0
	2,001-20,000	6	0	0
	> 20,000	0	0	
	(a)	1	0	
Sediments	(a)	9	0	0
All Surface Sites (excluding sanitary sewage)	0-200	53	3	6
	201-2,000	111	4	4
	2,001-20,000	113	15	13
	> 20,000	71	12	17
	(a)	23	0.5	

(a) Early samples, sediments and sludges – not tested

Table 3-47

COMPARISON OF THE FREQUENCY OF DETECTION OF SALMONELLA WITH LEVELS OF FECAL STREPTOCOCCI

	Fecal Streptococci		Salmonella	
Sample Source	Range MPN/100 ml	No. of Samples In Range	Number Positive	% Positive Findings
Sewage	0-200	0	0	0
	201-2,000	1	0	0
	2 001-20,000	2	1	50
	> 20,000	13	11	85
	(a)	6	4	
Storm Water Runoff	0-200	0	0	0
	201-2,000	5	2	40
	2,001-20,000	14	6	43
	> 20,000	21	5	24
Pond Effluents	0-200	58	2	3
	201-2,000	80	5	6
	2,001-20,000	35	9	26
	> 20,000	13	0	0
	(a)	13	5	
Streams	0-200	11	0	0
	201-2,000	39	1	3
	2,001-20,000	29	2	7
	> 20,000	5	1	20
Estuarine	0-200	14	0	0
	201-2,000	14	0	0
	2,001-20,000	4	1	25
	> 20,000	0	0	0
	(a)	7	0	
Sediments	(a)	7	0	0
All Surface Sites (excluding sanitary sewage)	0-200	83	2	2
	201-2,000	138	8	6
	2,001-20,000	82	18	22
	> 20,000	39	6	15
	(a)	27	5	

(a) Early samples, sediments and sludges – not tested

3.6 REFERENCES CITED

Bott, T.L., 1973, "Bacteria and the Assessment of Water Quality," *Biological Methods for the Assessment of Water Quality,* ASTM STP 528.

Driscoll, E. et al., September 1982, *Detention Basins for Control of Urban Stormwater Quality* (Draft), U.S.E.P.A. Water Planning Division, Washington, D.C.

Driscoll, E., December 1982, Personal Communication.

Driscoll, E., February, 1983, Personal Communication.

Geldreich, E.E., 1966, *Sanitary Significance of Fecal Organisms in the Environment,* U.S. Dept. of the Interior, Federal Water Pollution Control Administration, Cincinnati, Ohio.

Geldreich, E.E., Best, L.C., Kenner, B.A., and Van Donsen, D.J., 1968, "The Bacteriological Aspects of Stormwater Pollution," *Journal of Water Pollution Control Federation,* Vol. 40, p. 1861-1872.

Geldreich, E.E., 1978, "Bacterial Populations and Indicator Concepts in Feces, Sewage, Stormwater, and Solid Wastes," *Indicators of Viruses in Water & Food,* G. Berg editor, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.

Granai, C., and Sjogren, R.E., 1981, "In Situ And Laboratory Studies of Bacterial Survival using a Microporous Membrane Sandwich," *Applied and Environmental Microbiology,* Vol. 41, No. 1, p. 190-195.

Guerrera, A. et al., March 1981, *Quality Assurance Project Plan for the Nassau/Suffolk Urban Runoff Project,* submitted to U.S.E.P.A.

Kenner, B.A., and Clark, H.P., 1974, "Detection and Enumeration of Salmonella and *Pseudomonas aeruginosa,*" *Journal of Water Pollution Control Federation,* Vol. 46, No. 9, Sept., p. 2163.

Koppelman, L.E., 1978, *Long Island Comprehensive Waste Treatment Management Plan,* Long Island Regional Planning Board, Hauppuage, New York.

Lawler, Matusky, and Skelly, Engineers, and Fanning and Phillips, 1982, *Long Island Segment—Nationwide Urban Runoff Program,* Pearl River, N.Y.

Mallard, G.E., 1980 *Microorganisms in Stormwater—A Summary of Recent Investigations.* U.S. Geological Survey Open-file report 80-1198, 18 p.

Mitchell, R., and Chamberlin, C. 1978. "Survival of indicator organisms," *Indicators of Viruses in Water & Food,* G. Berg editor, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.

Olivieri, V.P., Kruse, C.W., Kawata, K., and Smith, J.F., 1977, *Microorganisms in Urban Stormwater,* U.S. Environmental Protection Agency, EPA-600/2-77-087.

Redman, J.H., 1979. *Accumulation and Elimination of Coliform Bacteria by Hard Clams* (Mercenaria mercenaria) *in Great South Bay (Babylon Cove vicinity) During the Summer and Fall, 1978,* Division of Marine Resouces, New York State Department of Environmental Conservation, Stony Brook, New York.

Seaburn, G.E., and Aronson, D.A., 1974, *Influence of Recharge Basins on the Hydrology of Nassau and Suffolk Counties, Long Island, New York.* U.S. Geological Survey Water-Supply Paper 2031, Washington, D.C.

Tetra Tech, 1977, *Water Quality Modeling, Hempstead Bay, Middle Bay, East Bay, South Oyster Bay, Great South Bay, Long Island, New York.* Prepared for Nassau-Suffolk (Long Island) Regional Planning Board.

U.S.D.A., 1976, *Nassau County Interim Soils Report, as amended 1982,* Nassau County Soil and Water Conservation District.

U.S.E.P.A., 1977. See Olivieri et al.

U.S.E.P.A., 1979, *A Statistical Method for the Assessment of Urban Stormwater.* U.S.E.P.A.-400/3-79-023, Washington, D.C.

U.S.E.P.A., 1982. See Driscoll et al.

Section 4 - The Surface Water Component; Remainder of the Island

4.0 INTRODUCTION

The importance of all Nassau and Suffolk shellfish lands as a commercial and recreational resource justifies a continuing concern for the protection or enhancement of estuarine water quality. These lands are located along the north shore, the eastern bays and the south shore. The shellfishing areas in the western portion of the south shore bays have been the subject of the detailed study described in Section 3.

Although time and funding did not permit a detailed evaluation of runoff related coliform problems affecting other Long Island estuarine waters as part of the NURP study, an overview of current and potential problems and possible control measures is presented below.

The New York State Department of Environmental Conservation has assigned best usage classifications to the tidal waters lying within the bi-county area. These range from **SA,** the most restrictive in respect to ambient water quality standards and the least restrictive in respect to usage, to **SD,** the least restrictive in respect to water quality standards and the most restrictive in respect to usage. The classifications reflect water quality and usage targets rather than existing conditions.

New York State regulations (6NYCRR 701.5) define the best usages for the saline surface water classifications as follows:

SA *...suitable for shellfishing for market purposes and primary and secondary contact recreation.*

SB *...suitable for primary and secondary contact recreation and any other use except for the taking of shellfish for market purposes.*

SC *...suitable for fishing and all other uses except for primary contact recreation and for the taking of shellfish for market purposes.*

SD *—All waters not primarily for recreational purposes, shellfish culture or the development of fishlife and, because of natural or man-made conditions, cannot meet the requirements of these uses.*

It is possible for waters in a given area to be assigned an **SA** classification and still remain uncertified for shellfishing. The extent of the areas currently closed to shellfishing is illustrated in Figure 3-1.

Preceding page blank

In order to understand the nature of the runoff-related problems, and the feasibility of control measures, it is necessary to consider the drainage areas that are tributary to the various estuarine water bodies. The boundaries of these areas were identified during the *Long Island Comprehensive Waste Treatment Management Plan* (Koppelman, 1978). In the course of the NURP, some of the boundaries were refined. Figure 4-1 is a bi-county map of these drainage areas.

Section 4.1 discusses Nassau County, and Section 4.2, Suffolk County. A general description of the embayments and their contributing drainage areas, estimated stormwater runoff pollutant loadings, current conditions affecting certification, and an assessment of the opportunities for protecting or improving water quality are included. Section 4.3 discusses priorities for action or further investigation.

4.1 NASSAU COUNTY

4.1.1 General Description

The Nassau County bays that were subject of the detailed study and mathematical modeling described in Section 3 are all located along the south shore. Although one control measure was tested at a north shore site (Perry Ave., Bayville), the findings there were considered applicable in the development of stormwater runoff control plans for south shore areas. The five additional bays, which were not included in the more intensive study—three located entirely within the County and two, Little Neck Bay and Cold Spring Harbor, located partially within Nassau and partially within New York City and Suffolk County, respectively—are the subject of the first portion of this overview.

Unlike the barrier-built embayments of the south shore, many north shore harbors display the long, relatively narrow shape typical of drowned stream valleys. Most are relatively shallow, and poorly flushed at their narrow southern extremities. Only Oyster Bay, which is separated from the Sound by a baymouth bar, differs in configuration.

There are approximately 81,700 acres of marine waters within Nassau County whose best usage, as determined by NYSDEC, is for taking of shellfish. These waters have been classified **SA** and include north and south shore bays and harbors, Long Island Sound and the Atlantic Ocean. Table 4-1 gives a breakdown of total acreage, acreage classified **SA,** and the number of acres actually open to the taking of shellfish for each bay and harbor within Nassau County.

The harbors or embayments and the watersheds or drainage basins contributing runoff to them are depicted in Figure 4-1. Topographically defined drainage basins along Nassau's north shore generally comprise the areas generating stormwater runoff that can ultimately reach the estuarine receiving waters. Inasmuch as the delineation of the topographic drainage basins was undertaken during the Long Island 208 study, and a review of the estimates of acreage contributing runoff to each of the embayments showed them to be sufficiently accurate and reasonable, no further refinement of the Nassau drainage basin boundaries was undertaken during the Long Island NURP.

Table 4-1

NASSAU COUNTY SURFACE WATER ACREAGE

Surface Water Body	Total Area (Acres)	Area Classified "SA" (Acres)	Area Classified Other Than "SA" (Acres)	Acres of "SA" Classified Waters Open to Shellfishing
Little Neck Bay (part)	715	0	715	—
Manhasset Bay	2,110	1,355	755	0
Hempstead Harbor	1,490	1,025	465	0
Oyster Bay	2,520	2,520	0	2,192
Cold Spring Harbor (part)	1,315	1,315	0	1,205
Long Island Sound	29,655	27,645	2,010	14,985
Atlantic Ocean	33,800	33,800	0	31,265
Hempstead Bay	2,575	1,710	865	0
Middle Bay	4,200	3,690	510	776*
East Bay	3,005	2,985	20	905
South Oyster Bay	5,750	5,670	80	1,590**
TOTAL	87,135	81,715	5,420	52,918

Total Permanently Certified for shellfishing (12/82) 52,918

Total Certified, Including Seasonal Certifications (12/82) 53,153 Acres

* Add'l. 33 acres open Oct. 1-Apr. 30 only.

** Add'l. 202 acres open Nov. 15 to Apr. 30 only.

Within each drainage basin there are small sub-areas that are associated with recharge basins. Some drainage basins contain major freshwater stream/pond systems. At the Unqua Pond, Massapequa, study site the size of the contributing drainage area varied depending upon the magnitude of the storm event. This was due to the presence of sub-drainage areas that were associated with recharge basins designed to retain/detain a portion of generated runoff flow. Areas with extensive freshwater systems and low density residential and/or open space land use can be expected to contribute runoff to estuarine waters only during storm events of great magnitude.

The degree to which portions of the topographic drainage basins generate runoff is also influenced by the type as well as the density of land uses, the extent of storm sewering, roadway characteristics (curbed or soft shoulder), land slope, and soil permeability.

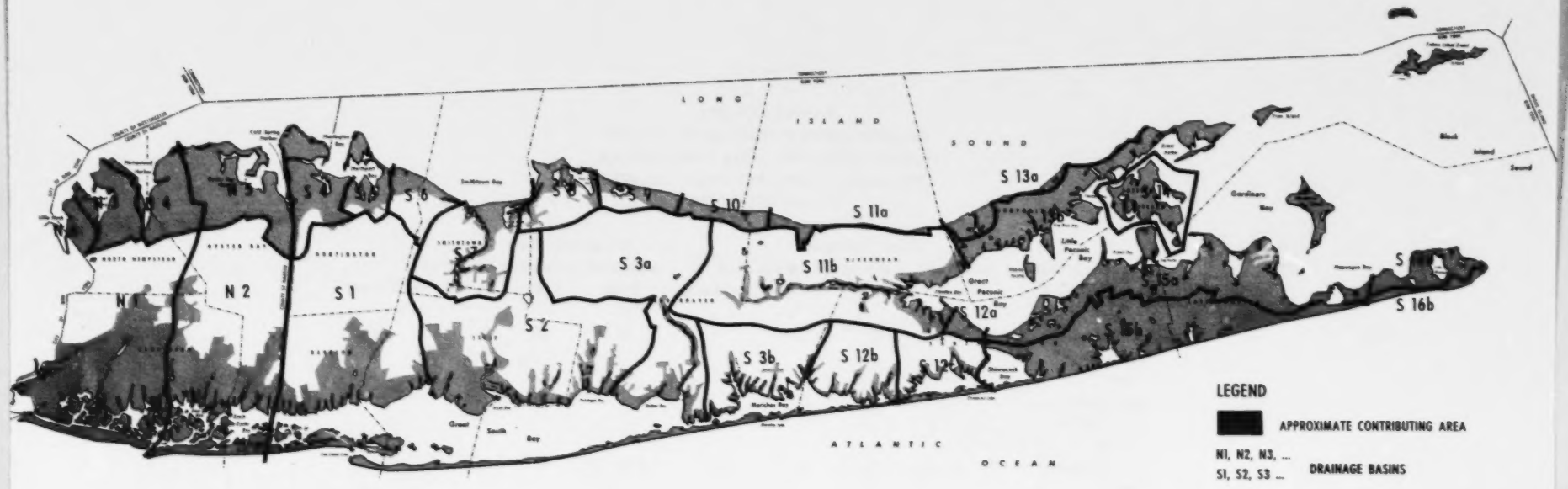


FIGURE 4-1 *Map showing boundaries of contributing drainage areas*

4.1.2 Stormwater Runoff Pollutant Loads

The Long Island 208 Study presented estimates of stormwater runoff pollutant loads to several embayments. Annual loads were derived by first calculating load factors for each of ten parameters, using the runoff data collected in the sampling program conducted during the 208 Study.

Table 4-2 presents the estimated annual total coliform and fecal coliform bacterial loads for Nassau County estuarine receiving waters (bays) and the relative contribution, expressed as a percent of the total load, attributable to runoff, freshwater stream base flow, and point sources. Bacterial loads from stormwater runoff were computed as the product of the 208 Study load factors (MPN/acre inch of rainfall), an annual rainfall of 44 inches and the acreage within the contributing drainage area. Implicit in these calculations are the assumptions that the entire drainage basin contributed runoff during all storm events and that all generated runoff is discharged, unattenuated, to the estuarine receiving waters. Coliform loadings from sources external to the bays were not included in the estimated annual bacterial loads. Therefore, the loads given in Table 4-2 represent a *worst case* situation and tend to overstate the contribution of stormwater runoff to receiving water annual bacterial loadings.

Data for total coliform bacteria are basically those that were presented in Section 2 of Volume 1 of the *Long Island Comprehensive Waste Treatment Management Plan* (Koppelman, 1978). For Hempstead Bay, Middle Bay, and Hempstead Harbor the contribution from point sources has been revised to reflect improvements in waste water treatment achieved since the original 208 evaluations were performed. Estimates of annual fecal coliform loads reflect a modification of that which was presented previously. The annual loads of fecal coliform bacteria in runoff to all bays have been recalculated by applying the load factor for medium density residential land use to all contributing drainage basin acreage excluding open space. Stream base flow and point source fecal coliform annual load data used in calculating total annual loads are the 208 data, except for the point source load to the south shore Hempstead and Middle Bay area. In this instance, the annual load reflects improved conditions brought about by the abandonment of the Freeport Sewage Treatment Plant, whose flow was diverted to the Cedar Creek Water Pollution Control Facility, and the improvement in effluent quality at the Bay Park Sewage Treatment Plant. The annual loads of both total and fecal coliforms for Little Neck Bay have been revised in order to reflect the current point source conditions.

Table 4-2

NASSAU COUNTY
RELATIVE CONTRIBUTION OF TOTAL AND FECAL COLIFORM BACTERIA FROM RUNOFF, STREAM BASE FLOW, AND POINT SOURCES TO SURFACE WATER

Receiving Water (208 Basin)	Total Coliform MPN/Year Total	Total Coliform Percent of Annual Load Runoff	Stream	Point Source	Fecal Coliform MPN/Year Total	Fecal Coliform Percent of Annual Load Runoff	Stream	Point Source
Hempstead—Middle Bays* (N-1)	4.3×10^{16}	97	2	1	7.8×10^{15}	99	1	—
East-South Oyster Bays* (N-2)	4.7×10^{16}	98	1	1	9.0×10^{15}	99	1	—
Manhasset Bay (N-3)	2.2×10^{16}	95	4	1	3.6×10^{15}	99	1	—
Hempstead Harbor (N-4)	2.9×10^{16}	93	7	—	5.0×10^{15}	98	2	—
Oyster Bay-Cold Spring Harbor (N-5)	4.8×10^{16}	99	1	—	7.3×10^{15}	99	—	—
Little Neck Bay** (N-6)	3.2×10^{16}	23	—	77	3.7×10^{15}	33	—	67

* Part of detailed study area. See Section 3.

** Includes only Nassau County contribution. Point source annual load is based on sewage treatment plant non-chlorinated effluent having arbitrarily ascribed total and fecal coliform MPN/100 ml values of 2.4×10^6 and 2.4×10^5, respectively.

As indicated in Table 4-2, on an areawide basis, stormwater runoff is the major source of coliform bacteria to estuarine receiving waters. In the case of Manhasset Bay and of Hempstead Harbor, there is a significant contribution from stream base flow. In addition, sewage treatment plant and other point source discharges are potential contributors of a larger proportion of the coliform load at those times when effective treatment is not attained.

4.1.3 Current Conditions Affecting Certification

LONG ISLAND SOUND — The Nassau County portion of Long Island Sound, extending from Little Neck Bay to Cold Spring Harbor, contains 29,655 acres, of which 27,645 acres are classified **SA**. The remainder, located at the extreme western end, is classified **SB**. Currently almost 15,000 acres, all of which are located to the east of Hempstead Harbor, are open to shellfish harvesting. The overwhelming bacteriological pollutant sources impacting the western end of the Sound consist of combined sewer overflows and sewage treatment plant effluent discharges to the East River. During dry weather, combined sewers carry sewage directly to the sewage treatment plants; during storm events, combined sewers carry runoff as well as sewage. When the flow rate is greater than the capacity of the treatment system, the excess flow is by-passed directly to the receiving waters. During storm events, untreated sewage is discharged together with runoff. Bacterial loading related to stormwater from the New York City, Westchester County and Connecticut far exceeds that which is contributed from northern Nassau County.

Long Island Sound bacteriological surface water quality data collected by the Nassau County Department of Health reveal an improvement in bacteriological water quality that is believed to be directly related to the improved quality of the sewage effluents attributable to the upgrading of New York City sewage treatment facilities discharging to the East River. Annual total coliform log-averaged densities for an area of Long Island Sound from the New York City/Nassau County boundary to the mouth of Hempstead Harbor have decreased steadily from about 1500 MPN/100 ml in 1976 to 196 MPN/100 ml in 1981.

In addition, the seasonal (May 15 to September 30) disinfection of sewage treatment plant effluents by New York City has been shown to reduce average coliform bacterial levels by approximately 50 percent in this section of Long Island Sound during that period, as well as in Little Neck Bay and the outer portions of Manhasset Bay and Hempstead Harbor. A smaller reduction in bacterial levels was noted during wet weather, probably due to the added impact of combined sewer overflows (Nassau County Department of Health, 1979).

LITTLE NECK BAY — Most of the 715 acres of waters within the Nassau portion of Little Neck Bay are classified **SB.** Best usage for this classification is primary contact recreation. Conformance with total and fecal coliform bacterial standards was 50 percent in 1981. Improvement in water quality in this bay is directly related to the sewage treatment practices of New York City. One sewage treatment plant, located in Nassau County, discharges an average of 1.5 MGD to the bay. Since 1980, treated effluent from this plant has been chlorinated from May 15 to October 15. Prior to the fall of 1979, chlorination was practiced year round.

MANHASSET BAY — Bacteriological water quality of Manhasset Bay, especially the outer portion, is strongly influenced by the water quality in western Long Island Sound. Concentrations of coliform bacteria throughout the bay are affected by point source discharges, fresh water stream flows, and especially by stormwater runoff. Runoff accounts for 95 percent of the estimated annual total coliform load and 99 percent of the estimated annual fecal coliform load. Overall conformance with assigned classification bacterial standards for 1981 was about 90 percent. Water quality in the **SA** classified areas of the bay, generally the outer portion, is not acceptable for shellfishing certification. Therefore, approximately 1,350 acres of potential shellfishing lands remain closed.

The confluence of Manhasset Bay with Long Island Sound is located at a point of minimal tidal excursion (east-west movement), so that resident bay water tends to move in and out of the bay with each tidal cycle. Therefore, bacterial loadings to this bay tend to remain there and are attenauted through die-off, predation, and other natural processes. The degree of dilution with Long Island Sound water is unkown; however, bacteriological water quality within this portion of the Sound tends to be poorer than that within Manhasset Bay.

Most of the runoff enters the bay through storm drainage systems that do not allow for detention and recharge of runoff to groundwater. In addition, the major portion of the contributing drainage area is not serviced by sanitary sewers, and illegal discharges of sanitary sewage to storm sewers and streams are known to occur. Manhasset Bay is used extensively for boating and contains numerous marinas. The potential exists for considerable pollutant loading from pleasure boating activity.

HEMPSTEAD HARBOR — There is a total of almost 1500 acres within this north shore harbor, of which the upper or northern two-thirds is classified **SA.** This portion of the bay is minimally impacted by loadings from New York City, Westchester and Connecticut. It exhibits an annual average total coliform level of approximately 200 MPN/100 ml (1981) with two-thirds of the sampling points in conformance with water quality classification bacterial standards. However, none of the approximately 1000 acres are certified for shellfishing.

Most of the lower harbor is classified **SB** and exhibits an average total coliform level of approximately 330 MPN/100 ml. Based upon the Nassau County Department of Health surface water monitoring data, 100 percent of sampling points are in conformance with the bacterial standard.

As indicated in Table 4-2, about 93 percent of the estimated annual total coliform load and 98 percent of the fecal coliform load to this bay is derived from stormwater runoff. Dry weather freshwater influents, e.g., streams, account for a small but significant percentage of the annual bacterial load. The major portion of the runoff and stream loadings originates from the eastern shore drainage areas, areas that are for the most part unsewered. The potential for illegal discharges of sanitary sewage is ever-present.

The main fresh water tributary to Hempstead Harbor is Cedar Swamp Creek, which has its headwaters at the southernmost boundary of the Hempstead Harbor topographic drainage basin. It drains an area of 7500 acres, a significant portion of the whole drainage basin. The *Long Island Comprehensive Waste Treatment Management Plan* indicated that only one-third of the 7500 acres actually contributes flow to the bay. The remaining 5,000 upstream acres are generally in low density residential and/or open space land use; runoff from this area would not be expected to contribute to stormwater flow to the bay except during storm events of considerable magnitude.

Improvements in bay water quality, especially within the southernmost portion of the harbor, can be expected with the abandonment of the Roslyn Sewage Treatment Plant, whose flow will be diverted to the Nassau County Cedar Creek Sewage Treatment Plant. Upgrading and reconstruction of the Glen Cove Sewage Treatment Plant has reduced the estimated point source total coliform load to the bay by approximately two orders of magnitude, from 5×10^{14} to 7×10^{12} MPN/year. In addition, **SA** classified waters at the mouth of Hempstead Harbor in Long Island Sound appear to meet shellfishing standards during dry weather from May 15 to September 30 (the New York City chlorination period). This area could eventually be eligible for conditional certification (Nassau County Dept. of Health, 1979).

Runoff-derived bacterial loading is the major remaining obstacle to recertification of most of the Hempstead Harbor **SA** waters.

OYSTER BAY/COLD SPRING HARBOR—The Oyster Bay-Cold Spring Harbor complex comprises the least impacted of the estuarine waters along Nassau County's north shore. Eighty percent of the 27,600 acre topographic drainage basin is situated in Nassau County, with the remainder in Suffolk County. The predominant land use is low density residential. Most of the incorporated villages located within this basin are zoned for two to five acre development. Extensive areas are currently in estates that can best be categorized as undeveloped (forest or meadow) or open space. There are five separate medium density residential communities containing limited commercial-industrial development. Three of these five are shoreline communities, where stormwater runoff drains primarily to the estuarine receiving waters . The Perry Avenue In-Line Storage Leaching System is located in one of these three (Section 3.1).

Approximately 58 percent of the 27,600 acre topographic drainage basin (16,000 acres) drains through six separate major freshwater stream/pond systems. Most of these 16,000 acres are in low density residential and open space land uses. The largest system, the Beaver Lake System, covers an area of about 7,000 acres. One tributary drains a predominantly medium density residential area of 2,200 acres, and the main stream drains a low density-open space area of 4,800 acres. After passing through successive impoundments and wetland areas, stormwater runoff flows through a 63 acre, 3-5 foot deep lake, affording considerable attenuation of pollutant loads before discharge to Mill Neck Creek, a tidal estuary. The remaining five systems, Factory Pond, Spring Lake, Mill River, Tiffany Creek and Cold Spring Brook, drain areas of from 367 acres to 4,500 acres; all contain one or more impoundments, and varying types and acreages of wetlands. For the most part the systems retain their original configurations with culverting of stream channels restricted to some medium density residential areas.

The Oyster Bay-Cold Spring Harbor complex supports a valuable shellfishing industry—a commercial oyster fishery and hard shell clamming. All 2,520 acres of bay bottom in Oyster Bay and 1,315 acres of bay bottom in the Nassau County portion of Cold Spring Harbor are in **SA** classified waters. Of these almost 2,200 acres in Oyster Bay and 1,025 acres in Cold Spring Harbor are certified for shellfishing.

According to Nassau County Department of Health water quality data, average total coliform levels in 1981 were 9 MPN/100 ml in Oyster Bay and 32 MPN/100 ml in Cold Spring Harbor. All coliform data for sampling points in Oyster Bay were within acceptable limits for assigned classifications, as were eighty percent of the data for sampling points in Cold Spring Harbor.

The current discharge of treated sanitary sewage from the Oyster Bay Sewage Treatment Plant does not appear to severely impact the bay water quality. An area around the plant outfall is closed to shellfishing. The remainder of the contributing drainage area is unsewered; however, use of on-site disposal systems does not appear to adversely affect bay bacteriological water quality, except in a few isolated locations where high groundwater levels have resulted in system failures.

4.1.4 Opportunities for Control Measure Application to Protect or Improve Water Quality

Stormwater runoff to the estuarine receiving waters of Nassau County has been implicated as the primary source of internal bacterial loading to all but one of the nine embayments located within the boundaries of the county. The magnitude and impact of runoff bacterial loadings varies from bay to bay, depending upon a number of factors, not the least of which are the land uses and activities within the contributing drainage basin.

For some bays, stormwater-derived bacterial loads are probably the primary reason for closure of potential shellfishing lands, while in other bays, internal point sources, including freshwater streams, together with runoff and boundary conditions, are believed to result in contravention of shellfishing standards and closure of potential shellfishing lands. In one bay complex, Oyster Bay-Cold Spring Harbor, small areas are closed to shellfishing due to localized problems or for precautionary reasons due to the presence of a treatment plant outfall.

LITTLE NECK BAY—Control of internal stormwater loading to this bay is unwarranted. The overriding wet weather impact on this bay apparently results from the water quality in the far western end of Long Island Sound. Tidal exchange occurs between Little Neck Bay and the water moving through the East River, which serves as a tidal strait connecting Long Island Sound with New York Harbor. Combined sewer overflows to the East River during wet weather, together with runoff bacterial loads introduced from the New York metropolitan area, provide sufficient baterial loading to western Long Island Sound and thence to Little Neck Bay to preclude any significant improvement in water quality that could result from complete control of non-point source (runoff) loading directly to the bay.

MANHASSET BAY—The drainage basin for this bay is heavily urbanized, with the highest density development occurring in the southern and eastern portions. The western portion of the basin is primarily in low-density residential land use. Development of the basin is fairly complete, with most new construction replacing previously built structures or occurring as spot development. New residential construction is occurring primarily in low density areas, where local zoning requires sites of two or more acres.

Bacterial concentrations in Manhasset Bay are due partly to internal point and nonpoint-source contributions and partly to impacts from Long Island Sound, with the relative contribution of each varying with changing conditions; i.e., seasonal chlorination of sewage effluents from New York City, the impact of which extends into Manhasset Bay.

The extensive use of this bay for pleasure boating creates a potential for the introduction of pathogenic enteric bacteria in sanitary water discharges to the

receiving water. Although no impact on indicator bacterial levels resulting from boating activity has been demonstrated, this does not preclude the possible introduction of significant numbers of pathogens. In the past, sporadic instances of elevated indicator bacterial levels in the vicinity of bathing beaches have been traced to illegal discharges of sanitary wastes from private residences or businesses located near the shoreline.

Opportunities for control of stormwater runoff exist; however, extensive control may not be justified in light of the other impacts to the bay.

HEMPSTEAD HARBOR—There are opportunities for maintenance of existing water quality, preventing degradation in some areas, and improving water quality in others.

The enforcement of existing regulations requiring on-site retention and recharge of stormwater runoff in all new development, both on the western shore and in the Cedar Swamp Creek drainage area; together with the preservation of the Cedar Swamp Creek channel and adjacent wetlands to assure the stream's continued ability to regulate flows and attenuate pollutant loads, could do much to maintain existing water quality.

Future control of runoff from the more intensively developed portions of the drainage basin could lead to sufficient improvement in receiving water quality to permit recertification for the taking of shellfish. The reconstruction or rehabilitation of existing storm sewers to incorporate the basic features of the Perry Avenue In-Line Storage Leaching System could help to reduce coliform loads. In those sub-sections of the topographic drainage basin not presently served by storm sewers, primarily medium density residential areas, the installation of storage leaching systems in order to retain the runoff from almost all anticipated storm events and to recharge it to groundwater could provide additional bacterial load reductions. In most sectors of the drainage basin there is adequate depth to groundwater to allow the use of a Perry Avenue type of drainage system.

Modification of Pratt Pond, an existing impoundment located at the mouth of Cedar Swamp Creek and serving as a detention and sedimentation basin, could improve the effectiveness of the pond in reducing the bacterial loads transported by the Creek.

Surveillance to detect and eliminate illegal discharges of sewage from the on-site disposal systems used in the unsewered portions of the drainage area is ongoing.

OYSTER BAY/COLD SPRING HARBOR—The generally acceptable bacteriological water quality of this bay complex could be maintained through the application of control measures such as those considered for Hempstead Harbor. Runoff from new development could be retained on-site and recharged to groundwater. In areas currently discharging runoff to the estuarine waters, drainage systems could be upgraded and provisions made for the retention and infiltration of most runoff volume wherever depth to groundwater permits. The installation of storm sewers in areas that do not have them, could include retention/recharge structures to attenuate the volume of runoff reaching the estuarine receiving waters. The construction of an in-line storage leaching drainage system in the Incorporated Village of Bayville has already effectively eliminated the annual runoff contribution from sixty-six acres of medium-density residential development.

All of the streams and associated freshwater wetlands tributary to the bays could be preserved and protected to insure their continued effectiveness as attenuators of runoff-related coliform loads. Direct discharges of runoff to freshwater wetlands could be prohibited.

Surveillance to detect and eliminate illegal discharges of sewage from the on-site disposal systems used throughout most of the contributing drainage area is ongoing.

4.2 SUFFOLK COUNTY

4.2.1 General Description

Suffolk County tidal waters, which extend northward to the Connecticut boundary in Long Island Sound and northeast to the New York State-Rhode Island line in Block Island Sound, encompasses approximately 240,000 acres within the north shore, south shore and eastern embayments. Of this area, about 14 percent is located along the north shore; 36 percent, along the south shore and 50 percent, in the eastern embayments. Table 4-3 lists the total acreage in the individual bays, and the number of acres open to shellfishing. An estimated 85 percent of the marine waters, exclusive of Long Island Sound and the Atlantic Ocean is classified as **SA**. The remainder is classified as **SB**, and in a few, small areas, **SC** or **SD**.

In the 208 study, it was assumed that the boundaries of the north shore embayment's contributing drainage areas followed the topographic divides. Like the Nassau north shore bays, these areas are characterized by steep slopes, and, in some cases, by considerable areas of open space and vacant land. There are comparatively few streams flowing into the Suffolk north shore bays. In fact, the only major northward flowing stream is the Nissequogue River, which discharges into Smithtown Bay.

Contributing runoff areas for south shore bays were defined in the 208 Study as the topographic drainage area south of Sunrise Highway plus an estimated *effective area* for those streams that extended to the north of Sunrise Highway. These areas, part of the glacial outwash plain, are characterized by gentle slopes and rapid percolation. There are many streams tributary to south shore bays. The areas contributing runoff to Western Great South Bay are urbanized and partially sewered. Those contributing to Eastern Great South Bay, Moriches Bay, Quantuck Bay, Shinnecock Bay, and Mecox Bay are less intensively developed and, generally, unsewered. Much of the existing development is concentrated at or near the shoreline.

Similarly, in the 208 Study, the boundaries of the East End contributing areas tended to follow the morainal ridges. On the North Fork, the boundaries follow the Harbor Hill morainal ridge, much of which is located very close to

Table 4-3

SUFFOLK COUNTY—TOTAL AREA OF SHELLFISHING WATERS AND AREA OPEN TO SHELLFISHING

Surface Water Body	Total Area (Acres)	Area Open to Shellfishing (Acres)
North Shore Bays		
Huntington Bay/Northport Harbor	6,090	5,310
Nissequogue River/Smithtown Bay	22,860	21,350
Stony Brook Harbor	860	860
Port Jefferson Harbor	1,550	900
Mount Sinai Harbor	460	450
South Shore Bays		
Western Great South Bay (Amityville to Nicholl Pt.)	30,430	26,160
Eastern Great South Bay (Nicholl Pt. to Smith Point)	33,450	31,770
Moriches Bay	10,900	6,470
Quantuck Bay	730	560
Shinnecock Bay	9,170	8,950
Mecox Bay	1,050	0
Atlantic Ocean	231,500	231,500
East End Bays		
Mattituck Bay	130	100
Gardiners Bay	48.950	48,950
Orient Harbor	3,560	3,560
Southold Bay	1,340	1,340
Little Peconic Bay	13,730	13,730
Cutchogue Harbor	560	558
Great Peconic Bay	19,060	19,060
Peconic River/Flanders Bay	3,090	2,310
Fishers Island Sound	7,990	7,080
Noyack Bay	3,540	3,540
Sag Harbor & Cove	580	420
Three Mile Harbor	1,025	1,025
Acabonack Harbor	310	310
Napeague Bay	9,140	9,140
Montauk Harbor	1,090	940

SOURCE: NYSDEC, Region I, Stony Brook, New York, 1982.

the Long Island Sound shore. Most of the North Fork drains southward to Peconic Bay, Shelter Island Sound, or Gardiners Bay. Except for the north shore bluffs, slopes are moderate to gentle, and much of the land is devoted to agriculture. As in the case throughout most of the East End, shoreline areas have been developed for resort and recreational use.

On the South Fork, the boundaries delineated in the 208 Study follow the Ronkonkoma morainal ridge. Land uses are similar to those on the North Fork, except for the presence of extensive open space. The north-facing slopes are generally steeper than the south facing slopes, except in the Napeaque-Amagansett area.

The islands are similar in character to the Forks, but less intensively developed.

As part of the NURP, efforts were made to improve upon the rather coarse approximations of the contributing drainage areas, and thereby refine the total loads to selected surface waters. Extensive field surveys were carried out to better define the boundaries of the drainage areas. The actual contributing areas of storm sewer systems, and the direct overland runoff area to the streams and bays were estimated. The acreage in each land use category within the drainage basins was then tabulated; the area of open space and vacant land was subtracted; and finally the total annual loads were calculated.

4.2.2. Stormwater Runoff Pollutant Loads

In the Long Island 208 study, estimates were presented for stormwater runoff pollutant loads to several embayments. Pollutant loads were derived by first calculating load factors for each parameter using the runoff data collected in the sampling program conducted during the 208 Study. Total annual loads were computed by multiplying together the load factors, annual rainfall, and the contributing drainage area.

Because the NURP estimates were computed for specific embayments, and the 208 Study presented loading information by major topographic basin, some manipulation of the 208 Study data was required for direct comparison of values. Table 4-4 presents the two sets of loads that were calculated for each bay, using the 208 Study medium density residential load factor applied to the two estimates of the size of the various drainage areas. The NURP loads are consistently lower than the 208 Study loads because the drainage areas estimated by the NURP field surveys are smaller than the *assumed* drainage areas used in the 208 Study.

Even though the NURP estimates are significantly lower than the original 208 Study loads, stormwater runoff remains the overwhelming source of coliform bacteria to surface waters on an areawide basis. Table 4-5 presents the relative contribution of total and fecal coliform bacteria from runoff, stream base flow, and point sources.

Although the revision of the drainage area boundaries did not alter the relative significance of stormwater runoff pollutant loads, it has provided a better understanding of the extent of the land area contributing to the problem.

Table 4-4

COMPARISON BETWEEN NURP AND L.I. 208 STUDY ESTIMATES OF ANNUAL RUNOFF BACTERIAL LOADS TO SURFACE WATERS

Receiving Water (NURP) Topographic Basin (208)	Drainage Area* (Acres)	Total Coliform (MPN/YR)	Fecal Coliform (MPN/YR)
Western Great South Bay**	15,600	4.3×10^{16}	7.0×10^{15}
Basins S1 + 1/3 S2	23,210	6.3×10^{16}	1.0×10^{16}
Eastern Great South Bay	3,300	9.0×10^{15}	1.5×10^{15}
Basins 2/3 S2 + S3a	19.700	5.4×10^{16}	8.8×10^{15}
Moriches Bay	1,130	3.0×10^{15}	5.1×10^{14}
Basins S3b + S12b	8,660	2.3×10^{16}	3.9×10^{15}
Shinnecock Bay	590	1.6×10^{15}	2.6×10^{14}
Basins S12c + 1/10 S15b	3,540	9.6×10^{15}	1.6×10^{15}
Peconic River/Flanders Bay	240	6.5×10^{14}	1.1×10^{14}
Basin S11b	2,130	5.8×10^{15}	9.5×10^{14}
Mount Sinai Harbor	150	4.1×10^{14}	6.7×10^{13}
Basin 1/4 S9	960	2.6×10^{15}	4.3×10^{14}
Port Jefferson Harbor	970	2.6×10^{15}	4.3×10^{14}
Basin 2/3 S8	5,220	1.4×10^{16}	2.3×10^{15}
Stony Brook Harbor	570	1.5×10^{15}	2.6×10^{14}
Basin 1/6 S7	3,150	8.6×10^{15}	1.4×10^{15}
Nissequogue River/Smithtown Bay	1,590	4.3×10^{15}	7.1×10^{14}
Basin 5/6 S7	15,900	4.3×10^{16}	7.1×10^{15}
Huntington Bay/Northport Harbor	5,690	1.6×10^{16}	2.6×10^{15}
Basins S4 + S5	42,480	1.2×10^{17}	1.9×10^{16}

* Open space and vacant land excluded.

** Part of detailed study area See Section 3 .

4.2.3 Current Conditions Affecting Certification

The western end of Great South Bay was the primary focus of the Suffolk County efforts in NURP, because of the importance of the shellfish resource, the substantial uncertified areas and the strong evidence that the only way to open the uncertified areas was to reduce the bacterial load from stormwater runoff. Recently the sewage treatment plants serving the Park Avenue and Harbor Club garden apartments, and the Southside Hospital sewage treatment plant, which had previously discharged into western Great South Bay were abandoned and the flow diverted to Suffolk County Sewer District No. 3.

Many of the other bays of Suffolk County also contain areas that are uncertified for shellfishing as shown in Table 4-3 and Figure 3-1. Selected areas that are currently uncertified for shellfishing are identified on Table 4-6 according to the stream(s) tributary to each closed area within a particular bay. The acreage of the runoff contributing drainage area is also indicated.

Some of the closed shellfishing areas receive effluent from municipal sewage treatment plants (e.g., Huntington Harbor, Northport Harbor, Port Jefferson Harbor, Peconic River/Flanders Bay, and Patchogue Bay). Additional areas in some embayments (e.g., Peconic River/Flanders Bay, Bellport Bay, Moriches Bay) have been closed because of discharges from duck farm sewage treatment plants. Despite recent requirements for duck farms to severely curtail daily discharges to surface waters, these areas have generally remained uncertified.

EASTERN GREAT SOUTH BAY—The closed areas of eastern Great South Bay are of special interest because it has been estimated that more than ten percent of the total clam population of that portion of the bay is located in these uncertified areas. More important, the clam population density is considered to be relatively high in the closed areas (USEPA, Region II 1982).

Eastern Great South Bay is generally classified **SA** except for relatively small areas near the mouths of several tributary streams, which are classified **SB** and **SC**, and the area near the mouth of the Patchogue River, which is classified **SD**. The potential for opening a major uncertified area in the vicinity of the Patchogue River is constrained by the presence of the Village of Patchogue Sewage Treatment Plant, which discharges its effluent to that stream.

Field surveys were conducted to delineate the runoff drainage area of the eighteen streams that flow into eastern Great South Bay. The survey information also included the locations of storm sewer outlets that discharge into the stream channels. Several of the streams, including the six listed in Table 4-6, which discharge to closed shellfishing areas, contain sizable impoundments that probably provide some attenuation of runoff pollutant loads to the bay. Although not included in the calculations in Table 4-4, there are substantial amounts of vacant land and open space within the drainage areas of these streams.

MORICHES BAY—Moriches Bay is another area that supports considerable commercial and recreational shellfishing, although there is no accurate accounting of the available numbers or distribution of clams. Most of the bay is classified **SA** except the areas near the mouths of many of the streams tributary to the bay, which are classified **SB** and **SC** and, in some cases, **SD**. Tidal portions of several streams, among them the Forge River, Terrell River, and Seatuck Creek, receive discharges from duck farms. Impoundments on some of the streams may reduce the runoff-related bacterial loading to the bay.

Table 4-5

SUFFOLK COUNTY
RELATIVE CONTRIBUTION OF TOTAL AND FECAL COLIFORM
FROM RUNOFF, STREAM BASE FLOW, AND POINT SOURCES TO SURFACE WATER

Receiving Water	Total Coliform MPN/YR Total	Total Coliform Percent of Annual Load Runoff	Streams	Point Source	Fecal Coliform MPN/YR Total	Fecal Coliform Percent of Annual Load Runoff	Streams	Point Source
Western Great South Bay*	4.6×10^{16}	98	2	NA	7.1×10^{15}	98	2	NA
Eastern Great South Bay	9.5×10^{15}	94	5	1	1.6×10^{15}	93	6	1
Moriches Bay	3.1×10^{15}	97	2	1	5.2×10^{14}	96	2	2
Shinnecock Bay	1.6×10^{15}	100	0	NA	2.6×10^{14}	100	0	NA
Peconic River/Flanders Bay	6.7×10^{14}	97	1	2	1.2×10^{14}	96	1	3
Mount Sinai Harbor	4.1×10^{14}	100	NA	NA	6.7×10^{13}	100	NA	NA
Port Jefferson Harbor	2.7×10^{15}	99	0	1	4.4×10^{14}	99	0	1
Stony Brook Harbor	1.5×10^{15}	100	NA	NA	2.6×10^{14}	100	NA	NA
Nissequogue River/Simthtown Bay	4.4×10^{15}	98	1	1	7.2×10^{14}	98	1	1
Huntington Bay/Northport Harbor	1.7×10^{16}	98	0	2	2.7×10^{15}	98	0	2

NA-Not Applicable.

*Part of detailed study area. See Section 3.

The impact of stormwater runoff is indicated by the fact that sizable sections of the bay, e.g., Harts Cove and Seatuck Cove, have recently been designated as conditionally certified. Conditionally certified means that shellfishing is permitted under specific dry weather conditions.

SHINNECOCK BAY—All of Shinnecock Bay, except for small areas near the mouths of a few streams and the Shinnecock Canal is classified **SA.** Surveys were completed for the twenty-one streams, canals and ponds that discharge to the bay. The presence of extensive areas of vacant land and open space is assumed to be largely responsible for the acceptable water quality, and the limited extent of the uncertified areas.

FLANDERS BAY—Flanders Bay contains segments that are classified **SA** and **SC,** and most of the areas near the tributary streams are classified either **SC** or **SD.** The closed area of Flanders Bay near the mouth of the Peconic River receives the effluents of the Riverhead Sewage Treatment Plant and several duck farms.

SHELTER ISLAND SOUND AND SAG HARBOR—There is an uncertified area along the northwest side of Shelter Island and another along the south side. These areas receive effluent from the Shelter Island Heights Sewage Treatment Plant, which discharges into Shelter Island Sound, and Village of Sag Harbor Sewage Treatment Plant, which discharges to Sag Harbor.

4.2.4 Opportunities for Control Measure Application to Protect or Improve Water Quality

In Suffolk the application of stormwater runoff control measures to protect the currently acceptable quality of the estuarine waters receiving drainage from the moderate to sparsely developed portions of the county appears to offer considerable promise. Application of the same or similar measures may not be as effective in achieving substantial reductions in the coliform loadings to waters that do not now meet the standards for certification. Even where such reductions can be achieved, the value of controlling stormwater runoff may be somewhat limited in several of the bays due to localized conditions. The following comments concerning selected embayments represent a preliminary assessment of the situation.

EASTERN GREAT SOUTH BAY—Substantial amounts of vacant land and open space in the vicinity of the streams discharging to eastern Great South Bay provide the potential for future development and the consequent need for preventive measures to preserve the generally satisfactory water quality. The opening of an uncertified **SA** classified area in the vicinity of the Patchogue River may be precluded because of the location of a sewage treatment plant outfall in the immediate area. The opening of part of Bellport Bay is also un-

Table 4-6

SELECTED AREAS UNCERTIFIED FOR SHELLFISHING AND CONTRIBUTING DRAINAGE AREA

Uncertified Areas	Contributing Drainage Area* (Acres)
1. Eastern Great South Bay	
a) Patchogue River	1150
Swan River	435
Mud Creek	100
b) Browns Creek (Sans Souci Lakes)	220
c) Carmens River	100
Beaverdam Creek	70
2. Moriches Bay	
a) Smith Point Area	
Unchachogue Creek	25
Johns Neck Creek	10
Pattersquash Creek	30
Canal e/o Pattersquash	50
Lawrence Creek	30
b) Forge River	370
Mud Creek	40
Senix Creek	110
c) Terrell River	110
d) Tuthill Cove	70
e) Hart Cove	80
f) Heils Creek	160
Little Seatuck Creek	—
Seatuck Creek	50
East River	60
Fish Creek	25
Canals	50
g) Speonk River	80
Beaverdam Creek	25
Creek e/o Beaverdam	40
Oneck Drain	20
3. Moneybogue Bay	40
4. Quantuck Bay	
a) Aspatuck Creek	75
Quantuck Creek	60

Table 4-6 (Cont'd)

Uncertified Areas	Contributing Drainage Area* (Acres)
5. Shinnecock Bay	
a) Penniman Creek	30
Stone Creek	20
Phillips Creek	30
b) Daves Creek	25
c) Weesuck Creek	35
d) Smith Creek	45
e) Wells Creek	25
f) Penny Pond	10
6. Peconic River/Flanders Bay	240
7. Smithtown Bay	
a) Nissequogue River	2,015

*Open space and vacant land excluded.

likely, in this instance because of discharges from duck farm sewage treatment plants. The area of Bellport Bay that is now closed because of past or current discharges of duck farm wastes will probably remain closed despite the relatively recent imposition of stringent controls on discharges to surface waters.

MORICHES BAY — As in the case of eastern Great South Bay, the potential for considerable additional development of the contributing drainage area indicates the importance of prevention as opposed to remediation. One stormwater control measure discussed in Section 3, the retention/detention ponds, could be effective. Land use controls could be employed to maintain residential densities at or near their current level. The areas of the bay that are now closed because of past or present duck farm waste discharges will probably remain closed.

For those portions of Moriches Bay that are conditionally certified, an assessment of the clam resource and the benefit of permanently opening conditionally open areas is needed before major efforts, such as pond modifications, are undertaken to control stormwater runoff from existing sources.

SHINNECOCK BAY — Inasmuch as almost all of Shinnecock Bay is certified, extensive stormwater runoff control for existing development is apparently unwarranted. The application of control measures in new subdivisions or other types of development could help to maintain the generally satisfactory water quality.

PECONIC RIVER/FLANDERS BAY—These waters receive effluent from the Riverhead Sewage Treatment Plant and from several duck farms. Any change in the status of the uncertified shellfish areas seems unlikely, even if the application of control measures were to result in a major reduction in runoff-related coliform loads. The application of stormwater runoff controls other than those associated with new development or redevelopment appears unwarranted.

NORTH SHORE EMBAYMENTS—Huntington Harbor - Northport Harbor, Smithtown Bay and Port Jefferson Harbor are the receiving waters for municipal sewage treatment plant effluents. Extension of the Huntington Sewage Treatment Plant outfall to a point farther out in the harbor, which is classified **SA,** is currently under consideration. Determination of the need for major stormwater runoff controls for developed areas should await the completion of the outfall extension, and the designation of the required buffer area by the NYSDEC.

Both Northport Harbor and Smithtown Bay are classified **SA.** However, the closed section of Northport Harbor, near the Northport Sewage Treatment Plant outfall and the closed area in Smithtown Bay near the Kings Park Sewage Treatment Plant outfall are unlikely candidates for certification even if stormwater runoff coliform loads could be completely eliminated. The tidal portion of the Nissequogue River, which flows into Smithtown Bay, is certified **SC,** as is Port Jefferson Harbor. Port Jefferson Harbor not only receives the effluent from the Port Jefferson Sewage Treatment Plant but also accommodates considerable barge and ferry traffic as well as recreational vessels. Conscience Bay and Setauket Harbor, which together with Port Jefferson Harbor form the Port Jefferson Harbor complex, are classified **SA.**

Nearly all of the Suffolk North Shore embayments, including Mount Sinai Harbor, have some or all of their waters classified **SA** and certified for shellfishing. The maintenance of existing low density or open space areas and, in the case of new development or redevelopment, the application of control measures such as recharge basins or the in-line storage leaching system, could suffice to maintain the existing acceptable water quality.

SHELTER ISLAND SOUND AND SAG HARBOR—In Shelter Island Sound and in Sag Harbor small areas adjacent to sewage plant outfalls are likely to remain closed. The retention of open space and vacant land, together with the application of runoff controls when and if development occurs, should assist in preserving the water quality of nearby areas.

4.3 PRIORITIES FOR ACTION OR FURTHER INVESTIGATION

As the preceding overview suggests, the implementation of stormwater runoff control measures designed to reduce or eliminate coliform bacterial loads would not necessarily assure the conditional or permanent recertification of all shellfish waters. The benefits derived from control measure application can be expected to vary from embayment to embayment, depending upon the ambient water quality; the amount of tidal flushing; the presence, if any, of sewage treatment plant outfalls; and the seasonal chlorination of the New York City sewage treatment plant effluents.

On the basis of the limited information now in hand, it appears that, on an areawide basis, the opportunities for preserving the quality of currently certified shellfish waters far exceed those for improving conditionally certified or uncertified waters.

The establishment of priorities for the prompt application of stormwater runoff control measures, or for the further investigation of the appropriate mechanisms, costs, and benefits of particular actions, is difficult, at best.

Although the protection of all currently acceptable shellfish waters is important, two areas with generally acceptable water quality, the Oyster Bay-Cold Spring Harbor complex and eastern Great South Bay, areas that are particularly vulnerable to the degradation that often accompanies development, could be accorded high priority for further investigation and action.

Two additional areas that are now closed to shellfishing, Hempstead Harbor and Huntington Harbor may offer opportunities for significant improvement and reopening of some shellfish waters under specific circumstances.

With respect to Hempstead Harbor, use could be made of a mathematical model to evaluate the effect of selected control measures on bay water quality, in order to determine whether recertification for shellfishing is possible. (See Section 5.4.)

As far as Huntington Harbor is concerned, this effort could await re-evaluation of bay water quality in the event that the sewage treatment plant outfall is moved, as has been recommended.

4.4 REFERENCES CITED

Koppelman, Lee. 1978. *Long Island Comprehensive Waste Treatment Management Plan,* Long Island Regional Planning Board; Hauppauge, New York.

Nassau County Department of Health, 1979. *Effect of Seasonal Chlorination at New York City Sewage Treatment Plants Upon Nassau County North Shore Surface Water Bacteriological Quality,* (internal report), Mineola, New York.

U.S.E.P.A., Region II, 1982, *Impact Assessment on Shellfish Resources of Great South Bay, South Oyster Bay, and Hempstead Bay, New York* (Draft), New York.

Section 5 - Findings, Conclusions, and Plan Recommendations

5.0 INTRODUCTION

The investigations conducted as part of the Long Island portion of the Nationwide Urban Runoff Program have provided answers to some old questions, raised new ones, addressed a major concern regarding the role of recharge basins, and lent further credibility to several of the assumptions and findings of the 208 study. The three year study has contributed to a better understanding of runoff, and of the functioning and mitigating effects of control measures already in place. It has demonstrated that there are no quick inexpensive solutions to the problem of runoff-borne coliform contamination of coastal waters.

The following pages present a summary of the more important findings, together with the conclusions to be drawn therefrom. Where appropriate both the findings and conclusions are related to prior statements that were made on the same topic in the *Long Island Waste Treatment Management Plan* (Koppelman, 1978). The findings and conclusions lead to a series of recommendations, including priorities for implementation. Finally, there is a brief discussion of the unanswered questions that require further research.

5.1 FINDINGS AND CONCLUSIONS

5.1.1 Groundwater

Finding 1. In the majority of storm events sampled, the ratio of the total volume of runoff to the volume of precipitation falling on impervious areas was less than one(Section 2.5.1).

Conclusion: *Most of the runoff into recharge basins is derived from rain that falls directly on impervious surfaces, except during storms of high intensity, high volume and/or long duration.*

Finding 2. Stormwater runoff concentrations of most of tne inorganic chemical constituents for which analyses were performed were generally low (Section 2.5.2.1). In most cases they fell within the permissible ranges for potable water; however, there were two notable exceptions:

- median lead concentrations in stormwater runoff samples collected at the recharge basin draining a major highway consistently exceed the drinking water standards;
- chloride concentrations generally increased by two orders of magnitude during the winter months.

Conclusion: *In general, with the exception of lead and chloride, the concentrations of inorganic chemicals measured in stormwater runoff do not have the potential to adversely affect groundwater quality.*

Finding 3. In most instances where there was an influx of lead into a recharge basin, there was considerable attenuation before the stormwater runoff reached the water table. The influx of chromium was generally much smaller than that of lead. In 15 out of 23 storm events, the calculated chromium loads in runoff were higher than those in groundwater. There was little or no removal of chloride as the stormwater moved through the unsaturated zone beneath the recharge basin. Owing to the low nitrogen levels in stormwater runoff, as compared to the background levels of nitrogen in groundwater on Long Island, it was impossible to determine the degree of nitrogen removal (Section 2.5.2.4).

Conclusion: *Infiltration through the soil is generally an effective mechanism for reducing lead and probably chromium from runoff on Long Island. Although the NURP findings concerning chromium are not conclusive, data from an industrial spill at Farmingdale indicate attenuation. Chloride is not attenuated. The effect of infiltration on nitrogen is undetermined.*

Finding 4. The number of coliform and fecal streptococcal indicator bacteria in stormwater range from 10^8 MPN to 10^{10} MPN per acre per inch of precipitation. Except in a few cases, these bacteria were not detected in the groundwater beneath the recharge basins studied. Where they were present, they were found in concentrations at or near the analytical detection limit (Section 2.5.2.3).

Conclusion: *Coliform and fecal streptococcal indicator bacteria are removed from stormwater as it infiltrates through soil.*

Finding 5. In the NURP study, the most commonly occurring organic compounds found in stormwater runoff were benzene, bis (2 ethyl hexyl) phthalate, chloroform, methylene chloride, toluene, and 1,1,1-trichloroethane (Section 2.5.2.2). Of these, methylene chloride was consistently found in concentrations greater than 8 µg/l.

Of the 14 samples (5 runoff and 9 groundwater) analyzed for 113 of the EPA-designated priority pollutants, there were four instances, three of them occurring in groundwater, in which a single constituent (not including phenols and cyanide), exceeded the New York State Department of Health guidelines (Section 2.5.2.2) for a single organic constituent in drinking water (Tables 2-12,13). Three of the four instances occurred in stormwater runoff or groundwater derived from the highway drainage area. The constituents detected are not related to normal vehicular traffic, and are most probably attributable to undetermined point sources.

When phenols data were excluded from consideration, the New York State guidelines for total organics in drinking water were exceeded in one of the five runoff samples and in two of the nine groundwater samples unrelated to sampled storm events.

The findings of the 208 Program (Koppelman, 1978) indicated the presence of a number of organic constituents also identified in the NURP study, particularly the halogenated hydrocarbons and phthalates, which are most often associated with industrial solvents and with plastics, respectively. Of the one runoff and eight groundwater samples from three sites (two highway basins and one residential basin) analyzed for up to 58 organic constituents, the stormwater sample and two groundwater samples exceeded New York State Department of Health guidelines for total organics in drinking water. One organic compound in runoff (chloroform) and two in groundwater (trichloroethylene and dibutylphthalate) were found in concentrations greater than 50 µg/l in one or more instances.

Conclusion: *In view of the need to assure groundwater of acceptable quality, further investigations of stormwater runoff as a possible significant source of organic chemicals are essential. In addition, the significance of illegal discharges of organic chemicals that runoff may carry into storm drains or recharge basins cannot be discounted. However, on the basis of the limited runoff data, along with the results of a substantial number of organic chemicals analyses from ongoing Long Island monitoring programs related to water supply, ambient groundwater quality and sources of pollution, it appears that no change in the use of recharge basins is warranted.*

Finding 6. Median values of total recoverable lead in runoff samples ranged from 275 µg/l at the Plainview recharge basin, which drains a major highway, to 19 µg/l at the Laurel Hollow recharge basin, which drains a low density residential area containing only minor roadways. Between these two, in order of decreasing lead concentrations, were Centereach (strip commercial with major roadway), Huntington (parking lot) and Syosset (medium density residential with minor roadways) (Section 2.5.2.1).

Conclusion: *Lead concentrations in runoff entering a recharge basin appear to be directly related to the extent and characteristics of the road network and the type and volume of traffic in the drainage area served by the basin.*

Finding 7. Although the recharge basins at Laurel Hollow and Syosset both serve residential areas, some constituents found in the basin soil at these sites displayed differences that may be explained by the length of time each basin has been in use. In general, soil at the recently constructed Laurel Hollow basin contained lower concentrations of lead and pesticides than did the soil at the Syosset basin, which was constructed in 1957 (Section 2.5.2.4).

Conclusion: *In addition to land use, the length of time that a recharge basin has been in use appears to affect the concentration of some pollutants in the basin soil. The limit of the ability of the soil to adsorb or otherwise retain these constituents is unknown.*

Finding 8. There was no discernible difference in the performance of the Centereach recharge basin that could be attributed to the presence of the permanent liner (Section 2.5).

Conclusion: *Plastic-lined basins with overflow to a recharge structure and unlined recharge basins are equally effective in recharging stormwater to the groundwater reservoir and in attenuating chemical constituents in stormwater.*

Finding 9. Plant growth on a basin floor enhances infiltration because the plant root system keeps the soil layer loose and permeable, and provides channels for infiltrating water (Section 2.5.2.4).

Conclusion: *Removal of basin vegetation is not necessary, and may indeed decrease the infiltration rate.*

5.1.2 Surface Water

A. General Findings and Conclusions.

Finding 1. The load of the chemical constituents in stormwater runoff that were evaluated during this study varied in response to the characteristics unique to individual storm events rather than in response to seasonal changes. The notable exception to this finding was chloride, which increased significantly in winter (Sections 3.1.4.2, 3.2.5.3 and 3.3.4.3ii).

Conclusion: *Any control of chemical constituents in runoff requires awareness of their year-round presence. The use of highway deicing salts in winter explains the high chloride concentrations found in runoff during that season.*

Finding 2. The drying of streambeds because of sewering, as predicted in the streamflow augmentation studies (Lawler, Matusky and Skelly, 1981, and Suffolk County, 1981) was observed during the NURP program. It has been observed in the case of East Meadow Brook.

Conclusion: *The expectation that streams will continue to dry up in response to sewering, coupled with the findings of the groundwater investigations that recharge of stormwater appears to remove indicator bacteria and to attenuate some of the chemical constituents evaluated, leads to the conclusion that the detention and recharge of runoff in dry streambeds may be a beneficial control measure.*

Finding 3. In the course of the streamflow augmentation studies, predictions were made of the amount of drying of streams to be expected (Lawler, Matusky and Skelly, 1981; Suffolk County, 1981). Table 5-1 displays results of the analysis for 16 streams in Nassau County and four streams in Suffolk County.

Conclusion: *The opportunity for the infiltration of runoff in dry streambeds should be included when considering streamflow augmentation. If flow augmentation were not undertaken for the streams in the sewered areas of southern Nassau County and southwest Suffolk County, portions of 20 streambeds would be available for reducing stormwater runoff to the bays by infiltration. In that event, according to the analysis summarized in Table 5-1, a maximum of 35 percent of storm flow in Nassau County streams could be removed, and 21 percent in the four Suffolk County streams affected by base flow reductions. There could also be some degree of bacterial removal. In any event, reductions in flow to the impoundments, where they exist, would be achieved. In some cases, effluent overflow may even cease. This flow reduction would, in turn, cause a corresponding improvement in the ability of the impoundments to reduce bacterial loads.*

Finding 4. Two categories of runoff to estuarine waters have been observed. One category is the upland runoff that enters the freshwater portions of streams, and is conveyed thereby to the bays. The other category is overland runoff that enters the bays, directly or by way of the tidal portions of the streams. Along the South Shore, Merrick Road in Nassau and Montauk Highway in Suffolk (See Figure 4-1) mark the approximate location of the northern boundary of the areas contributing overland runoff (Section 3.4.3.1).

Estimates have been made of the quantities of runoff, and the pollutant loads in each runoff category, for the south shore from the Queens/Nassau border, in the west, to the Connetquot River, in the east. The values input to the computer model, in order to calculate the effect on the areas currently closed to shellfishing, were various fractions of the overland and stream pollutant loads removed. The results, displayed in Table 3-41, show that, if 95 percent of stream runoff is controlled and no overland runoff is controlled, 18 percent of the closed acreage in Nassau County and 14 percent in Suffolk County is reopened. If no stream runoff is controlled, but 95 percent of overland runoff is controlled, only 30 percent of the closed acreage in Nassau County is reopened, and none of the closed acreage in Suffolk County is reopened. Finally, if 95 percent of both overland and stream runoff are controlled, 99 percent of the acreage in Nassau County and 79 percent in Suffolk County could be reopened.

Table 5-1

PERCENT OF RUNOFF EXPECTED TO INFILTRATE IN STREAMS REACHES DRIED BECAUSE OF GROUNDWATER LOWERING CAUSED BY SEWERING[1]

STREAM NAME	Total Contributing Drainage Area (Acres)	Drainage Area Contributing To Dry Stream Length (Acres)	Predicted Stream Drying Length (ft)	Percent of Flow Infiltrated
NASSAU COUNTY				
Pines Brook	4,647	4,594	8,600	19
Mill Creek	2,297	2,297	4,300	19
Powell Creek	748	320	600	6
Parsonage Creek	1,617	659	1,100	7
Baldwin Creek	1,378	0	0	0
Milburn Creek	1,366	729	4,000	19
East Meadow Creek	6,868	6,868	24,200	35
Cedar Swamp Creek (East & West)	1,281	1,218	11,500	65
Newbridge Creek	477	434	4,100	32
Bellmore Creek	344	251	2,700	48
Bellmore Creek East (East Br. & West Br.)	2,192	2,025	21,800	74
Seamans Creek	675	471	5,300	44
Seaford Creek	710	701	7,900	56
Massapequa Creek	3,711	3,439	27,800	65
Unqua River	549	471	1,800	28
Carmen Creek	1,910	654	2,500	10
				35 Overall
SUFFOLK COUNTY				
Amityville Creek	713	314	4000–4500	36
Neguntatogue Creek	566	119	2000–2500	19
Santapogue River (East & West)	2,689	1,102	3000–4000	10
Willets Creek	734	367	5000–5500	50
				21 Overall

[1] Lawler, Matusky and Skelly, 1982

Conclusion: *In order to achieve substantial openings of uncertified shellfishing lands, it would be necessary to control both stream runoff and overland runoff. To control one without the other would yield little benefit.*

Finding 5. Modeling studies (see Appendix F) have indicated that there is a high degree of mixing and flushing in the South Shore Bays of Nassau County. This implies that the control of runoff discharge from any individual stream will not result in sufficient localized improvement in receiving water quality to warrant the reopening of any uncertified shellfishing acreage. Hence, it is almost impossible to obtain an improvement in one specific portion of a bay, unless controls are implemented throughout an extensive tributary drainage area. In Suffolk County, Great South Bay has less tidal mixing and flushing in the nearshore areas, making it possible to achieve site-specific reductions.

Conclusion: *Significant improvement in the bacteriological water quality in the South Shore bays of Nassau County to the east of East Meadow Brook requires the simultaneous control of both the upland and overland flows discharging to the eastern bays. In the Great South Bay, in Suffolk County, certain individual areas can be improved by the control of upland and overland flows associated with selected individual streams.*

Finding 6. In order to obtain an estimate of the costs required to achieve some of the improvements indicated in Table 3-41 and of the benefits to be realized, a series of five alternative plans was selected from a number of alternatives prepared by the consultant (Section 3.4.4). These alternatives, listed in Table 3-42, represent different levels of effort, and are presented according to the anticipated degree of runoff control. Also listed are the acreages of shellfishing lands reopened by the implementation of each plan alternative. Table 5-2 provides a tabulation of the estimated costs to implement each plan. Three caveats are in order: the first is that the estimates were made before further work indicated that once a week street sweeping was of doubtful value in reducing total coliform load; the second is that the assumed existence of sufficient depth to groundwater for the installation and effective operation of leaching catch basins south of Merrick Road – Montauk Highway is also highly doubtful; finally, the degree of bacteria removal in Plan 1 was assumed to be equal to the percentage of the flow infiltrated into the dry streambeds, and this, also, is questionable.

The amount of control associated with each of the Plans is uncertain of achievement. Nevertheless, Table 5-2 is useful in showing the relative magnitude of the costs associated with various possible control programs.

Table 5-2

SUMMARY OF COSTS AND DEGREES OF CONTROL OF PLAN ALTERNATIVES

Control Measure Plans	NASSAU COUNTY Costs for Control Measures ($1000) Capital	Annual[a]	No. of Acres Opened	Cost Per Acre Opened ($)	SUFFOLK COUNTY Costs of Control Measures ($1000) Capital	Annual[a]	No. Acres Opened	Cost Per Acre Opened ($)
1. Minimal Action. Increase infiltration in dry stream beds (use of stop logs)	640	75	996	75	70	8	0	—
2. Plan 1 plus stream control (increased pond storage from Bellmore Creek east; use of gabions and dredging)	800	100	1,642	67	5,000 (750)[b]	786 (114)[b]	1,105	711 (103)[b]
3. Plan 2 plus further stream control (additional pond storage) in Seamans, Seaford, Carmans (sand filter) and Santapogue (new pond) Creeks, and in Carlls River	1,600	204	1,642	124	5,100	798	1,105	722
4. Plan 3 with 50% overland control east of Bellmore Creek (dog ordinances and street sweeping once a week [50% removal assumed] in overland area)	1,600	371	1,642	226	5,100 (980)[b]	1,014 (389)[b]	2,351	431 (166)[b]
5. Control on all streams with 75% overland control throughout (leaching catch basins in overland area)	23,100	3,064	6,873	446	9,000 (4,500)[b]	1,393 (620)[b]	4,519	308 (137)[b]

[a] Capital cost amortized at 10% over 20 years plus operation and maintenance costs.

[b] Plan modified to exclude all expenditures that do not contribute to the opening of additional acreage.

A review of Tables 3-42 and 5-2 shows that in Nassau, Plans 1, 2, and 5 result in reopening of from 9 to 62 percent of the currently uncertified acres at a per acre cost of $75 for Plan One, $67 for Plan Two, and $466 for Plan Five. Plans Three and Four do not result in additional opened acreage above that achieved in Plan Two. Therefore additional expenditures for added control measures in excess of those included in Plan Two are unwarranted unless the maximum possible control is achieved through implementation of Plan Five. In Suffolk County modified versions of Plans Two, Four and Five result in the reopening of from 14 to 56 percent of the currently uncertified acres within the Great South Bay at a per acre cost of $103 for Plan Two, $166 for Plan Four, and $137 for Plan Five.

Table G-1 of Appendix G presents the estimated value of the clam population in place, in certain nodes in the Great South Bay. The estimate is based on the following price ranges:

Little necks:	13¢ to 18¢ per clam
Cherrystones/chowders:	4¢ per 12¢ per clam
Seed clams:	14¢ to 18¢ per clam

On a per acre basis, the total resident clam population, in all three categories, is valued at $1,866 to $2,817. The clam population estimates were made in 1978-9 (USEPA, Region II, 1982), and there is evidence that the population has declined since that time (Regional Marine Resources Council, 1983).

Conclusion: *It is possible that the annual value of the clams that could be harvested from a given acre of reopened shellfish land may compare favorably with the annual cost of reopening that acre. However, the three caveats regarding the feasibility and effectiveness of the control measures, discussed above, together with the imprecision of the clam population data, make it inadvisable to incur large-scale costs for control measures at this time.*

Finding 7. The coastal waters of Long Island receive coliform loads from three types of sources (Section 4.1). These are point sources such as sewage treatment plant outfalls, stream base flow, and stormwater runoff. Table 4-2 lists the percentages that each category contributes to Nassau County receiving waters. Table 4-4 lists the same information for Suffolk County receiving waters. The data presented are for both total and fecal coliforms. In all but one case, runoff contributes at least 93% of total and fecal coliforms.

Conclusion: *Stormwater is the major source of coliform loading to Long Island bays, and the major cause of shellfishing area closures from Bellmore Creek in Nassau County to Connetquot River in Suffolk County. Outside of this area, even if it were possible to control all runoff, certification of all shellfishing lands would still not be achieved, since shellfishing is not permitted within a NYSDEC — specified distance of any sewage treatment plant outfall, regardless of water quality. Furthermore, some of the bays in Suffolk County contain areas where impaired water quality exists for reasons other than stormwater runoff (e.g. localized duck farm discharges).*

Finding 8. Ratios of fecal coliform to fecal streptoccoccal bacteria (FC/FS) found in runoff were low. At the five recharge basin sites, median FC/FS values ranged from 0.05 to 0.20. At three of the sites, maximum values were less than 2.0, the other two being above 5.0. At the Bayville surface water site, FC/FS values ranged from 0.008 to 0.219, and at Unqua Pond, they ranged from 0.002 to 0.86. Finally, at the Central Avenue site, all but two FC/FS values were between 0.040 to 0.690. The others were less than 2.0.

Conclusion: *Ratios of fecal coliform bacteria to fecal streptococci (FC/FS) were less than 1.0 in the overwhelming majority of samples analyzed. FC/FS values greater than 4.0 are generally considered to be of human origin and values less than 0.7 of animal origin. The evidence accumulated in this study strongly supports the belief that fecal coliform loads are derived from a non-human source.*

Estimates indicate that the dog population could be a major source of the fecal coliform load in stormwater runoff (Driscoll, April 1982). However, the estimates had a wide range of uncertainty, and if dogs were indeed the main source, the FC/FS ratio should have been far lower, i.e. 0.002 to 0.02, than most of the values cited above. Dogs and birds are common throughout the study area, but the data are not sufficiently conclusive to permit identification of any individual source or combination of sources.

Finding 9. Local conditions such as the presence of sewage treatment plant outfalls, duck farm waste treatment plants and commercial marine transport activity may negate the effectiveness of reductions in coliform bacteria in achieving the desired reopening of closed shellfishing areas. Much of the land within the drainage areas contributing stormwater runoff to currently certified shellfishing waters is in low density residential or open space use (Section 4.1.3 and 4.2.3). The effect of any future development of portions of this land will depend, to a considerable degree, on the provisions made for the management of runoff (Section 4.1.4 and 4.2.4).

Conclusion: *The information now in hand indicates that, on an areawide basis, the opportunities for preserving the quality of currently certified or certifiable waters far exceed those for improving the quality of conditionally certified or uncertified waters.*

B. Site-Specific Findings and Conclusions.

1. Perry Avenue, Bayville, Nassau County.

Finding 1a): For the Perry Avenue system, calculated long term reductions of stormwater runoff volume due to percolation and storage were determined to be 93.5 and 89 percent, respectively, using the USEPA methodology (Driscoll et al., September, 1982) and Long Island rainfall statistics. The overall flow reduction achieved by the system is a function of both percolation and storage and was determined to be 99.3 percent (Section 3.1.4.3).

Conclusion: *Based upon the above analysis and upon the fact that approximately one hundred storm events occur, on the average, during a given year in the Nassau-Suffolk Region, the in-line storage leaching drainage system can be expected to generate a discharge to estuarine receiving waters once every 1.4 years.*

Finding 1b): In general, the bacteriological quality of the runoff influent flow was comparable to that reported for the other study sites.

For the limited number of events during which there was overflow from the leaching catch basin, increases in mean concentrations were noted for each of the three indicator bacteria groups (Section 3.1.4.2).

Conclusion: *The increase in coliform concentrations in leaching catch basin overflows suggests that the catch basin may provide conditions favorable to coliform proliferation. This, in addition to the need to maintain leaching capability, makes it desirable that such catch basins be regularly cleaned of accumulated sediments and organic materials.*

2. Unqua Pond, Massapequa, Nassau County.

Finding 2a): Surveyed storm events producing up to 1.17 inches of rain had associated bacteriological reductions of better than 90 percent. Surveyed storm events with greater than 1.17 inches of rain had associated bacteriological reductions considerably below 90 percent (Section 3.2.6.3).

Conclusion: *Bacteriological reductions appear to be related to the following two factors: the runoff volume generated by a storm event relative to the pond volume and the surface overflow rate applied to the pond during each storm event. Reduction of bacterial loads remains high (more than 90 percent) until a threshold range, which is a function of the above two factors, is attained. Thereafter pond removal efficiency decreases sharply.*

Finding 2b): More than 90 percent reduction of bacterial indicator loads in storm water runoff is obtained as runoff passes through the impoundment for storm events with associated calculated f values equal to or greater than 22. The f factor is equal to the quotient of the volume ratio (basin volume/storm runoff volume) divided by the surface overflow rate (average runoff rate of flow/pond surface area). The 90th percentile storm, i.e. the storm whose size is exceeded by only 10 percent of the expected storm events, produces approximately 1.18 inches of rain. This storm size is associated with f values in the range of 17 to 20 (Section 3.2.6.3).

Conclusion: *Unqua Pond can be expected to reduce bacterial concentrations or loads by more than 90 percent, during 90 percent of expected storm events.*

Finding 2c): Based upon dye studies of the pond, hydraulic short circuiting is assumed to occur to a greater or lesser degree during the majority of storm events including those events associated with better than 90 percent reductions in bacteriological indicator organism concentrations (Section 3.2.6.1).

Conclusion: *Bacteriological removals of 90 percent or more can be obtained despite the occurrence of hydraulic short circuiting and relatively short hydraulic detention times. Therefore, the mechanism for bacteriological removals in the pond appears to be more a function of the surface overflow rate than of the hydraulic detention time and the mechanism for removal appears to be primarily sedimentation rather than bacteriological die-off.*

Finding 2d): During three storm events, large increases in the concentrations of fecal coliform bacteria measured in the pond effluent could not be accounted for by the measured influent concentrations. Copious amounts of fecal waste from waterfowl are known to accumulate on the eastern shore of the pond and on the adjacent parking lot. Runoff from the shore has been observed entering the pond. The parking lot has a storm drainage system that discharges directly to the pond (Section 3.2.6.2).

Conclusion: *The most probable source of the additional load is fecal material washed off areas adjacent to the pond, where waterfowl tend to congregate. The amount so introduced varies with individual storm characteristics, but it can be assumed that, during almost all storms, a fecal coliform load over and above that carried in by the main influent stream is introduced into the pond. It can therefore also be assumed that additional fecal streptococci are brought in by the same route. It may be concluded that the impoundment functions efficiently in reducing bacterial loading, but that removal efficiencies would be improved if the resident waterfowl population were reduced.*

3. Central Avenue, Deer Park, Suffolk County.

Finding 3a): A statistical analysis of summer data indicated that the increased frequency of street cleaning practiced at the Central Avenue site resulted in an appreciable (48 percent) reduction of fecal coliforms; a marginal (15 percent) reduction of total coliforms; and essentially no reduction of fecal streptococci (Section 3.3.4.3a).

Results of similar statistical analysis of the data from the remainder of the sampling events were not presented for the reasons cited in Section 3.3.4.3a. Nevertheless, comparison of the spring and fall data before street cleaning, with the data for the same time periods after street cleaning, indicated that no reduction in any of the three bacterial indicators had occurred.

Note that the control plans evaluated in Finding 6 of Part A of Section 5.1.2 are based on total coliform while the New York State regulations for shellfishing have two sets of coliform standards, fecal and total.

Conclusion: *Street sweeping does not appear to be a viable control measure for total coliforms and fecal streptococci. It may provide some limited benefit with respect to the removal of fecal coliforms.*

Finding 3b): In the majority of the storm events sampled, runoff coefficients (i.e. the ratio of the measured runoff volume to the total precipitation volume falling on the drainage area) exceeded the fraction of the total drainage area that was impervious. The inconsistency of this finding with Groundwater Finding Number 1 may be explained by the fact that the percentage of the total runoff derived from the pervious and impervious surfaces varies, depending on such factors as total precipitation, rainfall intensity, antecedent precipitation, and frozen ground conditions (Sections 3.3.4.1).

Conclusion: *Even in drainage areas with relatively permeable soils and flat topography, a portion of the runoff may come from precipitation on pervious surfaces. Although not specifically addressed in the sampling program, the fact that runoff can be derived from pervious surfaces may help to explain the limited capability, if any, of street sweeping in removing indicator bacteria.*

Finding 3c): The ratios of warm weather (May to October) load factors to cold weather load factors (November to April) were as follows (see Table 3-28):

Non-fecal coliforms	14:1
Fecal coliforms	12:1
Fecal streptococci	3:1

Conclusion: *There appears to be a seasonal variation in the indicator bacteria concentrations in stormwater runoff. The effect of this seasonal variation upon the efficiency of street cleaning is unclear.*

Finding 3d): *Once a week street sweeping did not produce consistent reductions in EMC's, loads, and load factors for the chemical parameters sampled.*

Conclusion: *Street sweeping is apparently not an effective control measure for the chemical pollutants measured.*

Finding 3e): The average total and fecal coliform load factors (MPN/acre/inch) calculated for the NURP were somewhat lower than those reported in the Long Island 208 Study (Section 3.3.4.3(a)).

Conclusion: *The use of Long Island 208 Study indicator bacteria load factors yields a conservative estimate of total annual loads to receiving waters of Suffolk County as well as the region (Section 4.1, 4.2).*

5.2 RECOMMENDATIONS

5.2.1 Groundwater

The Long Island NURP investigations have evaluated a number of contaminants present in runoff to recharge basins and those detected in the groundwater beneath the basins. Based on the results of this study, and notwithstanding the identified need for further investigations, and site specific water quality assessments, the following general recommendations are offered:

GW 1 *Continue to use recharge basins wherever feasible for the disposal of stormwater and the replenishment of groundwater.*

GW 2 *Avoid maintenance practices that would interfere with the natural revegetation of basins by grasses and shrubs.*

GW 3 *Use "ecological recharge basins" only where their aesthetic value justifies the additional cost.*

GW 4 *Consider the use of in-line storage leaching drainage systems, or components thereof, as a substitute for recharge basins in areas, other than parking lots, where maintenance will be assured and where the value of the land for development purposes is greater than the cost of installing and maintaining the underground system. Storage leaching drainage systems should also be considered for use where the installation of recharge basins is not feasible.*

GW 5 *Prevent illegal discharges to drainage systems or recharge basins. Such discharges, which often result from improper storage or deliberate dumping of chemicals, must be controlled at the source.*

5.2.2 Surface Water

The NURP investigations have raised questions concerning the probable effectiveness and/or feasibility of large-scale runoff control measures in achieving shellfishing water quality standards. Therefore, the following recommendations involving minimum-to-moderate costs are proposed:

SW 1 *To maintain existing water quality where it is currently satisfactory:*

a) *Preclude any additional direct discharge of stormwater runoff into surface waters, using all available means for detention and/or recharge to reduce bacterial loads.*

b) *Protect stream corridors from encroachment, so that the stream reaches that will become dry because of the lowering of the water table due to sewering will always be available for stormwater detention and recharge.*

c) *Inform local officials and the public regarding the nature and cost of the nonpoint source controls that must accompany further development or redevelopment and of needed changes in current practices relating to dog waste clean-up and disposal and public feeding of waterfowl.*

SW 2 *To improve water quality in those areas where modest reductions in coliform counts could lead to the conditional opening of currently uncertified areas or the unconditional opening of conditionally certified or uncertified shellfishing areas:*

a) *Preclude any additional direct discharge of stormwater runoff into surface waters, using all available means for detention and/or recharge to reduce bacterial loads.*

b) *Protect stream corridors from encroachment, so that the stream reaches that will become dry because of the lowering of the water table due to sewering will always be available for stormwater detention and recharge.*

c) *Inform local officals and the public regarding the nature and cost of the nonpoint source controls that must accompany further development or redevelopment and of needed changes in current practices relating to dog waste clean-up and disposal and public feeding of waterfowl.*

d) *Initiate studies, including mathematical modeling where appropriate, to identify the most promising opportunities for effecting changes in certification status at reasonable cost.*

e) *Initiate pilot programs designed to encourage the proper clean-up and disposal of canine fecal material and to discourage public feeding of waterfowl, in order to determine the impact of such programs on receiving water quality.*

SW 3 *To achieve some portion of an important beneficial use of areas currently in violation of the standard for the taking of shellfish:*

a) *Investigate the physical, political and economic constraints on the wider use of controlled shellfish harvesting in conjunction with depuration or transplanting to certified areas.*

b) *Devise measures for minimizing or overcoming those constraints.*

SW 4 *Pursue the investigation, begun with the Salmonella study, to identify and quantify the presence of human enteric pathogens in stormwater runoff and in the receiving waters. For sewage, a relationship has been established between the presence of total and fecal coliforms and the associated presence of human pathogens. However, over 90% of the coliform load in estuarine waters is contributed by stormwater. Therefore, investigations into whether such a relationship exists for stormwater should be continued and expanded.*

5.3 THE IMPLEMENTATION PROGRAM

The following pages present a brief description of both the immediate and long term activities that will be required in order to carry out the recommendations. The proposed programs or measures have been keyed to the recommendations through the use of the same two letter (**GW** for groundwater; **SW** for surface water) and numerical identifier. Thus proposed implementation activity **GW 1** has been designed to carry out recommendation **GW 1.**

Several measures that are expected to assist in the maintenance of satisfactory water quality where it now exists, and the improvement of water quality where it is now marginal, have been listed twice in order to present a comprehensive program of implementation activities for each situation.

5.3.1. Determination of Priorities

The findings and conclusions of the Long Island Segment of the Nationwide Urban Runoff Program and the recommendations that follow suggest that the assignment of priorities for remedial action based upon the severity of discrete problems affecting limited geographic areas is generally inappropriate. Therefore the identification of several of the recommendations for inclusion in an immediate action program represents the authors' judgment as to their implementability rather than as assessment of the magnitude of their potential contribution to the mitigation of stormwater runoff-related water quality problems. In weighing the suitability of each of the recommendations, such factors as the availability of appropriate technology, public acceptability, and the absence of major legal, administrative or fiscal obstacles have been considered. Clearly, those recommendations that call for a continuation or expansion of current activities are prime candidates for an early action program. Those that may require changes in public attitudes and behavior, or those that call for additional study must be regarded as part of a long-term program. Table 5-3, which lists the proposed activities as *immediate action, immediate initiation-continuing effort,* and *long term or future action,* provides a tentative implementation schedule.

5.3.2 Selection of Implementing Agencies

The implementation of both the early action and the long term programs pose a very different problem from that involved in the implementation of point source controls. Unlike point source controls, for which implementing agencies are clearly identifiable, nonpoint source controls by their very nature require concurrent action by numerous agencies and individuals. In the case of runoff-borne contamination significant improvements can only be achieved through parallel, coordinated efforts of legislators and administrators at all levels of government and of informed citizens.

The identification of candidate agencies, which has been included in the implementation program description and in Table 5-3, should be regarded as an indication of those expected to assume primary, but not necessarily exclusive, responsibility for implementation. Participation by other agencies and individuals is anticipated.

5.3.3 The Program

The implementation program comprises a series of measures directed primarily at the maintenance of the quantity of groundwater recharge and the preservation or modest improvement of ground and surface water quality through continued use of traditional stormwater runoff controls, such as recharge basins and detention ponds, and on innovative measures, such as in-line storage leaching drainage systems or system components. It involves the application of best management practices; the improved enforcement of existing laws and regulations and, in a few instances, the enactment or promulgation of new ones; and the maintenance of an ongoing research effort (see 5.4 for a discussion of needed research). As in the case of the findings and conclusions and the recommendations (5.1.1, 5.1.2 and 5.2.1, 5.2.2), proposed actions affecting groundwater and surface water are presented separately, and in that order.

GW 1 New York State, Nassau and Suffolk Counties, and those municipalities that construct, prescribe standards for, or accept dedication of recharge basins should generally continue to rely on this device.

GW 2 No implementation program required.

GW 3 The New York State Department of Transportation, which currently shares it ecological recharge basin construction expertise with interested parties, when it receives a specific request, should work with the Long Island Regional Planning Board and the County agencies to facilitate access to prototype designs and other relevant information.

GW 4 The Nassau County Department of Public Works and the Nassau County Department of Health should assist the Long Island Regional Planning Board in publicizing the in-line storage leaching drainage system and its components for stormwater runoff disposal in areas where insufficient space or inadequate depth to groundwater preclude the use of recharge basins.

GW 5 New York State and Nassau and Suffolk Counties should increase surveillance of the storage, handling and disposal of toxic and hazardous materials and should increase enforcement of existing controls.

SW 1 a–Nassau and Suffolk Counties and municipalities should supplement existing New York State regulations by enacting local legislation or amending site plan review procedures to ban further direct discharges of stormwater runoff into receiving waters. (The Long Island Regional Planning Board is providing guidance in the form of the Nonpoint Source Handbook, which contains recommendations, and schematics and working drawings, where appropriate, in order to assist state, county and local agencies and private developers in complying with runoff control regulations). The Counties and the municipalities should classify the major repair or reconstruction of any drainage system currently discharging directly to receiving waters as a Type I Action under SEQRA, unless the repair or reconstuction will result in the reduction or elimination of the direct discharge.

SW 1 b–Nassau and Suffolk Counties, assisted by the U.S. Geological Survey, should identify and map dry streambeds—those portions of the stream corridors that are currently dry but known to have been covered by constant or intermittent flow within recent years. The map should be updated as additional reaches become dry. The Counties should enact stream corridor protection ordinances prohibiting the physical alteration of and the temporary or permanent placement of structures and/or of impervious materials on the stream beds and those areas within the boundaries of the stream corridors that require protection.
The Nassau County Department of Health and the Suffolk County Department of Health Services, in cooperation with the New York State Department of Environmental Conservation, the County Departments of Public Works, and interested municipalities, should undertake stream corridor studies for those areas (generally, but not necessarily, outside the detailed study area) that contribute runoff to the shellfish lands described above, in order to identify opportunities for the installation of effective control measures or the initiation of programs at minimal cost.

SW 1 c–The Long Island Regional Planning Board, assisted by the 208 TAC agencies, should continue and expand both its technical assistance and public information functions, to the maximum extent that staff and funding permit, in order to gain public understanding and support for nonpoint source control implementation in general, and dog waste clean up and disposal controls and waterfowl feeding controls in particular.

SW 2 a–Nassau and Suffolk Counties and municipalities should enact local legislation or amend site plan review procedures to ban further direct discharges of stormwater runoff into receiving waters. (The Long Island Regional Planning Board is providing guidance in the form of the Nonpoint Source Handbook, which contains recommendations, and schematics and working drawings, where appropriate, in order to assist state, county and local agencies and private developers in complying with runoff control regulations). The Counties and the municipalities should classify major repair or reconstruction of any drainage system currently discharging directly to estuarine waters as a Type I Action under SEQRA unless the repair or reconstruction will result in the reduction or elimination of the direct discharge.

SW 2 b–Nassau and Suffolk Counties, assisted by the U.S. Geological Survey should identify and map dry streambeds—those portions of the stream corridors that are currently dry but known to have been covered by constant or intermittent flow within recent years. The map should be updated as additional reaches become dry. The Counties should enact stream corridor protection ordinances prohibiting the physical alteration and the temporary or permanent placement of structures and/or of impervious materials on the streambeds and those areas within the boundaries of the stream corridors that require protection.

The Nassau County Department of Health and the Suffolk County Department of Health Services, in cooperation with the New York State Department of Environmental Conservation, the County Departments of Public Works, and interested municipalities, should undertake stream corridor studies for those areas (generally, but not necessarily, outside the detailed study area) that contribute runoff to the shellfish lands described above, in order to identify opportunities for the installation of effective control measures or the initiation of programs at minimal cost.

SW 2 c–The Long Island Regional Planning Board, assisted by the 208 TAC agencies, should continue and expand both its technical assistance and public information functions, to the maximum extent that staff and funding permit, in order to gain public understanding and support for nonpoint source control implementation in general, and dog clean up and waste disposal controls and wildfowl feeding controls in particular.

SW 2 d–The New York State Department of Environmental Conservation, Nassau County Department of Health and Suffolk County Department of Health Services should review existing surface water data and obtain additional data as necessary to facilitate the ranking of shellfish lands according to the magnitude of the improvement required either to 1) obtain unconditional certification of conditionally certified shellfish lands or 2) obtain unconditional or conditional certification of presently uncertified lands. Each of the County Health Departments should review its listing of the highest ranked conditionally certified or uncertified shellfish lands (those requiring the least improvement to obtain a change in status) to determine whether or not the achievement of reductions in runoff-related coliform loads would be sufficient to obtain the desired change in status.

The County Health Departments should evaluate existing drainage basins and stormwater collection systems in order to identify the part or parts of the system contributing the greatest coliform loads and assess the opportunities for, and potential benefit of, implementing remedial measures.

SW 2 e–The Long Island Regional Planning Board, with the assistance of the County Health Departments, and one or more municipalities, should design and carry out a three year pilot program to evaluate compliance with and the degree of improvement obtained through the application of dog waste clean up and disposal controls within a geographically limited area. Such a program, should include a receiving water quality assessment.

The Long Island Regional Planning Board, with the assistance of the County Health Departments and one or more municipalities, should design and carry out a three year pilot program to evaluate compliance with the degree of improvement obtained through the application of dog waste clean up and disposal controls within a geographically limited area. Such a program, should include receiving water quality assessment.

SW 3 a–The Regional Marine Resources Council should prepare a preliminary work plan and investigate funding sources for the recommended study of constraints on the wider use of controlled shellfish harvesting, depuration or transplanting.

The Marine Resources Council, acting as lead agency, should assume study management responsibility and should also provide technical input to the above described study, at such time as funding becomes available. The County Health Departments, New York State Sea Grant, the Marine Sciences Research Center at Stony Brook, the towns, and other interested persons or institutions should participate to the extent that their individual or agency role or special expertise permits.

SW 3 b–The Long Island Regional Planning Board, with the assistance of the Marine Resources Council, New York State Department of Health, the County Health Departments and Region 1 of the New York State Department of Conservation should identify a series of alternative measures for minimizing or overcoming the constraints now limiting depuration or transplanting, and should select and urge implementation of one or more of those regarded as feasible and cost beneficial.

SW 4 The Nassau County Department of Health and the Suffolk County Department of Health Services should expand their routine surface water monitoring programs to include a limited evaluation of the bacterial species constituting the indicator coliform bacterial groups. Speciation of bacteria from selected water samples will assist in the determination of the sanitary significance of the indicator bacteria present in the receiving water following storm events.

The Nassau County Department of Health and the Suffolk County Department of Health Services should continue the evaluation of the estuarine receiving waters for the presence of the pathogenic

Table 5-3

SUMMARY OF PROPOSED IMPLEMENTATION PROGRAM AND SCHEDULE

Recommendations	Implementing Action	Responsible Agency or Agencies	Timing
GW 1 Continue to use recharge basins wherever feasible for the disposal of stormwater and the replenishment of groundwater.	Continue to rely on recharge basins wherever space, depth to groundwater and water supply considerations permit.	New York State, Nassau and Suffolk Counties, and municipalities.	Immediate initiation—continuing effort.
GW 2 Avoid maintenance practices that would interfere with the natural revegetation of basins by grasses and shrubs.	No implementation program required.		
GW 3 Use "ecological recharge basins" only where their aesthetic value justifies the additional cost.	Facilitate sharing of the New York State Department of Transportation's ecological recharge basin expertise, and access to prototype designs and other relevant information.	The New York State Department of Transportation, the Long Island Regional Planning Board and the County agencies.	Immediate initiation—continuing effort.
GW 4 Consider the use of in-line storage leaching drainage systems, or components thereof, as a substitute for recharge basins in areas, other than parking lots, where maintenance will be assured and the value of the land for development purposes is greater than the cost of installing and maintaining the underground system. These systems should also be considered for use where the installation of recharge basins is not feasible.	Publicize the in-line storage leaching drainage system and its components for stormwater runoff disposal in areas where insufficient space or inadequate depth to groundwater preclude the use of recharge basins.	The Nassau County Department of Public Works and the Nassau County Department of Health and Long Island Regional Planning Board.	Immediate initiation—continuing effort.
GW 5 Prevent illegal discharges to drainage systems or recharge basins. Such discharges, which often result from improper storage or deliberate dumping of chemicals must be controlled at the source.	Increase surveillance of the storage, handling and disposal of toxic and hazardous materials and enforcement of existing controls.	New York State and Nassau and Suffolk Counties.	Immediate initiation—continuing effort.

Table 5-3

Recommendations	Implementing Action	Responsible Agency or Agencies	Timing
SW 1 To maintain existing water quality where it is currently satisfactory:			
a) Preclude any additional direct discharge of stormwater runoff into surface waters, using all available means for detention and/or recharge to reduce bacterial loads.	a. Enact local legislation or amend site plan review procedures to ban further direct discharges of stormwater runoff into receiving waters. (The Long Island Regional Planning Board is providing guidance in the form of the Nonpoint Source Handbook, which contain recommendations, and schematics and working drawings, where appropriate, in order to assist state, county and local agencies and private developers in complying with runoff control regulations).	a) Nassau and Suffolk Counties and municipalities.	Immediate action.
	Classify the major repair or reconstruction of any drainage system currently discharging directly to receiving waters as a Type I Action under SEQRA, unless the repair or reconstruction will result in the reduction or elimination of the direct discharge.	Nassau and Suffolk Counties and municipalities.	Immediate action.
b) Protect stream corridors from encroachment, so that the stream reaches that will become dry because of the lowering of the water table due to sewering will always be available for stormwater detention and recharge.	b. Identify and map dry streambeds—those portions of the stream corridors that are currently dry but known to have been covered by constant or intermittent flow within recent years. The map should be updated as additional reaches become dry.	b) Nassau and Suffolk Counties, assisted by the U.S. Geological Survey.	Immediate action. (Map update, continuing effort.)
	Enact stream corridor protection ordinances prohibiting the physical alteration and the temporary or permanent placement of structures and/or of impervious materials on the streambeds and those areas within the boundaries of the stream corridors that require protection.	Nassau and Suffolk Counties.	Immediate action.
	Undertake stream corridor studies for those areas (generally, but not necessarily, outside the detailed study area) that contribute runoff to the shellfish lands described above, in order to identify opportunities for the installation of effective control measures or the initation of programs at minimal cost.	The Nassau County Department of Health and the Suffolk County Department of Health Services, in cooperation with the New York State Department of Environmental Conservation, the County Departments of Public Works, and interested municipalities.	Immediate initiation - continuing effort.

Table 5-3

Recommendations	Implementing Actions	Responsible Agency or Agencies	Timing
SW 1 c) Inform local officials and the public regarding the nature and cost of the nonpoint source controls that must accompany further development or redevelopment and of needed changes in current practices relating to dog waste clean-up and disposal and public feeding of waterfowl.	c. Continue and expand both technical assistance and public information functions, to the maximum extent that staff and funding permit, in order to gain public understanding and support for nonpoint source control implementation in general, and dog clean up-dog waste disposal controls and waterfowl feeding controls in particular.	c) The Long Island Regional Planning Board, assisted by the 208 TAC agencies.	Immediate initiation - continuing effort.
SW 2 To improve water quality in those areas where modest reductions in coliform counts could lead to the conditional opening of currently uncertified areas or the unconditional opening of conditionally certified shellfishing areas:			
a) See SW1.a.	See SW1.a.	See SW1.a.	See SW1.a.
b) See SW1.b.	See SW1.b.	See SW1.b.	See SW1.b.
c) See SW1.c.	See SW1.c.	See SW1.c.	See SW1.c.
d) Initiate studies to identify the most promising opportunities for effecting changes in certification status at reasonable cost.	d) Review existing surface water data and obtain additional data as necessary to facilitate the ranking of shellfish lands according to the magnitude of the improvement required either to 1) obtain unconditional certification of conditionally certified shellfish lands or 2) obtain unconditional or conditional certification of presently uncertified lands.	d) The New York State Department of Environmental Conservation, Nassau County Department of Health and Suffolk County Department of Health Services.	Immediate initiation — continuing effort.
	Review the Nassau and Suffolk listings of the highest ranked conditionally certified or uncertified shellfish lands (those requiring the least improvement to obtain a change in status) to determine whether or not the achievement of reductions in runoff-related coliform loads would be sufficient to obtain the desired change in status.	Nassau County Department of Health and Suffolk County Department of Health Services.	Long term or future action.
	Evaluate existing drainage basins and stormwater collection systems in order to identify the part or parts of the system contributing the greatest coliform loads. Assess the opportunities, for, and potential benefit of, implementing remedial measures.	Nassau County Department of Health and Suffolk County Department of Health Services.	Long term or future action.

Table 5-3

Recommendations	Implementing Actions	Responsible Agency or Agencies	Timing
SW 2 e) Initiate pilot programs to encourage the proper clean-up and disposal of canine fecal meterial and to discourage public feeding of waterfowl, in order to determine the impact of such programs on water quality.	e) Design and carry out a three year pilot program to evaluate the degree of improvement obtained through the application of dog waste clean-up and disposal controls within a geographically limited area. Such a program should include receiving water quality assessment.	e) The Long Island Regional Planning Board, with the assistance of the County Health Departments, and one or more municipalities.	Long term or future action.
	Design and carry out a three year pilot program to evaluate compliance with and the degree of improvement obtained through the enactment of a ban on the feeding of waterfowl at a selected public access feeding area. Such a program should include receiving water quality assessment.	The Long Island Regional Planning Board, with the assistance of the County Health Departments and one or more municipalities.	Long term or future action.
SW 3 To achieve some portion of an important beneficial use of areas currently in violation of the standard for the taking of shellfish: a) Investigate the physical, political and economic constraints on the wider use of controlled shellfish harvesting in conjunction with depuration or transplanting to certified areas.	a) Prepare a preliminary work plan and investigate funding sources for the recommended study of constraints on the wider use of controlled shellfish harvesting, depuration or transplanting.	a) The Regional Marine Resources Council	Immediate initiation—continuing effort.
	The lead agency, should assume study management responsibility and should also provide technical input to the above described study, at such time as funding becomes available.	The Regional Marine Resources Council, the County Health Departments, New York State Sea Grant, the Marine Sciences Research Center at Stony Brook, the towns, and other interested persons or institutions.	Long term or future action.
b) Devise measures for minimizing or overcoming the constraints investigated in a).	b) Identify a series of alternative measures for minimizing or overcoming the constraints now limiting depuration or transplanting, and select and urge implementation of one or more of those regarded as feasible and cost beneficial.	b) The Long Island Regional Planning Board, with the assistance of the Marine Resources Council, New York State Department of Health, the County Health Departments and Region 1 of the New York State Department of Conservation.	Long term or future action.

Table 5-3

Recommendations	Implementing Actions	Responsible Agency or Agencies	Timing
SW 4 Pursue the investigation begun with the Salmonella study, to identify and quantify the presence of human enteric pathogens in stormwater runoff and in the receiving waters. For sewage, a relationship has been established between the presence of total and fecal coliforms and the associated presence of human pathogens. However, over 90% of the coliform load is estuarine waters is contributed by stormwater. Therefore, investigations into whether such a relationship exists for stormwater should be continued and expanded.	Expand routine surface water monitoring programs to include a limited evaluation of the bacterial species comprising the indicator coliform bacterial groups. Speciation of bacteria from selected water samples will assist in the determination of the sanitary significance of the indicator bacteria present in the receiving water following storm events.	The Nassau County Department of Health and the Suffolk County Department of Health Services.	Immediate initiation—continuing effort.
	Continue the evaluation of the estuarine receiving waters for the presence of the pathogenic bacteria, Salmonella.	The Nassau County Department of Health and the Suffolk County Department of Health Services.	Immediate initiation—continuing effort.

bacteria, Salmonella. This should be accomplished in conjunction with routine surface water monitoring, especially during and following periods of stormwater runoff to the bays.

5.4 Needed Research

5.4.0. Introduction. Questions frequently arise during the course of planning and environmental studies, either in response to findings or to concerns that could not have been envisioned *a priori*. Often there is a need to continue or expand the scope of investigations undertaken during the initial study; either in order to gain greater understanding of observed phenomena, or to obtain further confirmation of specific findings and increased confidence in their usefulness. The Long Island Segment of the Nationwide Urban Runoff Program, like so many other studies, has generated its share of unanswered questions. The four groundwater and surface water research proposals described below could go a long way toward resolving many of the major questions. These investigations are essential in view of the high costs associated with implementation of certain of the control measures, and the public health implications of the unresolved questions.

5.4.1. Groundwater Research. The magnitude of the health risks associated with the ingestion of certain heavy metals and organic compounds makes even the slightest potential for runoff-related contamination of groundwater a continuing concern. A three year, three part study should be undertaken to further investigate the fate of heavy metals and organic compounds, including pesticides, in stormwater routed to recharge basins; to identify the locus of and mechanisms responsible for any removal of these constituents that occurs during infiltration to the groundwater reservoir; and to investigate the potential for future remobilization of undesirable constituents due to soil saturation or changing environmental conditions.

An additional three-year study should be undertaken to confirm the assumption that recharge basins and dry stream corridors are equally effective in respect to the recharge of stormwater runoff, the reduction of bacterial loads and the removal of heavy metals and organic compounds.

The key NURP participants—the Long Island Regional Planning Board, the U.S. Geological Survey, the Nassau County Department of Health, and the Suffolk County Department of Health Services—should assume responsibility for study design and work plan implementation.

5.4.2. Surface Water. The NURP provided the opportunity to examine the pollutant reduction capability of a single impoundment, Unqua Pond, in considerable detail. Unfortunately, it did not provide the time or level of funding required for the study of additional impoundments to permit an evaluation of the relationships between impoundment characteristics and pollutant reductions and to assess needs for pond modifications. In order to remedy this information gap, a two year, two part study should be undertaken to evaluate the long term average pollutant reduction capabilities of currently existing freshwater impoundments differing in their areal and bathymetric configurations and contributing drainage areas; and to determine what modifications would be required to improve their long term performance to levels needed to attain receiving water quality suitable for shellfishing certification or other best usage.

The Long Island Regional Planning Board should assist the Nassau County Department of Health, the Suffolk County Department of Health Services, and the Nassau County Department of Public Works in the design and execution of the work plan for the proposed investigations.

The Salmonella investigation, commenced as part of the NURP, was limited in scope and the extent of data collection. For this reason, it is not yet possible to develop a comprehensive set of conclusions regarding pathogens. At best, departmental budgets can cover only minimal levels of further sample collection and analysis and data evaluation. Therefore, in order to facilitate the timely acquisition of the data base needed to evaluate the extent to which the currently accepted bacterial indicators, total and fecal coliform, reflect the sanitary quality of the estuarine waters receiving stormwater runoff, a three year, two part study should be undertaken. The study should include, first, an investigation of the relationships between total and fecal coliform indicator bacterial densities and the presence and densities of selected pathogenic organisms including, but not necessarily limited to, salmonella and vibrios, and of alternative indicators such as bacterial iophages (coliphages) in runoff, receiving waters, bottom sediments and shellfish. Second, it should include an expansion of the speciation of bacteria obtained from runoff and receiving waters that yield positive reactions in coliform MPN analyses. Speciation should be conducted whenever preliminary evaluations indicate the presence of considerable numbers of bacterial species having limited or questionable sanitary significance, e.g., ubiquitous soil bacteria, including Klebsiella species. Comparisons of bacterial species present in stormwater runoff and in fresh and saline receiving waters are expected to further define the relative bacteriological impact of runoff on receiving waters and the sanitary significance of runoff as a source of bacteriological pollution.

The Long Island Regional Planning Board should assist the Nassau County Department of Health and the Suffolk County Department of Health Services in publicizing the need and seeking funds for the proposed investigations. In view of the specialized nature of the proposed investigations, participation by the Planning Board should be limited.

5.5 REFERENCES CITED

Driscoll, E., April 1982, Personal Communication.

Driscoll, E., et al., September, 1982, *Detention Basins for Control of Urban Stormwater Quality* (Draft), U.S.E.P.A. Water Planning Division, Washington, D.C.

Koppelman, L.E., 1978, *Long Island Comprehensive Waste Treatment Management Plan,* Long Island Regional Planning Board, Hauppauge, New York.

Lawler, Matusky and Skelly, Engineers, 1981, *Streamflow Augmentation Study, — Appendix L, Environmental Impacts from Sewering: No Action Report,* Pearl River, New York.

Regional Marine Resources Council, 1983, *Long Island Hard Clam Resource Management: Research Needs,* Hauppauge, New York. (In Press).

Suffolk County, 1981, *Milestone II Report on the No-Action Alternative — Study to Determine the Necessity and, if Applicable, the Methods of Mitigating the Decrease in Streamflow and Related Effects Associated with Sewering Suffolk County Sewer District No. 3 and Nassau County Sewer District No. 3 Long Island, New York,* Hauppauge, New York.

U.S.E.P.A., Region II, *Impact Assessment on Shellfish Resources of Great South Bay, South Oyster Bay, and Hempstead Bay, New York.* (Draft Report), New York 1982.

Section 6 - Annotated Bibliography

Altieri, R.H., 1983, Detection of Salmonella in the Environment.

A modified MPN procedure was used to quantitate Salmonella in a variety of environmental samples. Data with respect to source, frequency of detection, and speciation is presented, as well as a discussion of the significance of the findings. Statistical evaluation of Salmonella findings in relation to established sanitary indicator bacteria is provided.

Guerrera, A.A., et. al., *Quality Assurance Project Plan for the Nassau/Suffolk Urban Runoff Project,* submitted March 1981.

The document discussed quality assurance objectives for the collection, landling and analysis of water samples, and established the necessary standardized procedures for sampling, transportation, internal quality control, laboratory analysis, validation and reporting.

Hawkins, G.W., and Simmons, D.L., (in review), *Graphing rainfall-runoff data and calculating volume of runoff with a Tektronix 4051 graphic system:* U.S. Geological Survey WRD Bulletin.

This report describes a program written in BASIC computer language for a Tektronix 4051 (a desk top computer with screen graphics). The program was developed to graph storm rainfall and runoff data and to compute the volume of runoff discharged into a stormwater recharge basin using data recorded on a 16-channel paper tape.

Lawler, Matusky and Skelly, Engineers, and Fanning and Phillips, 1982, *Long Island Segment — Nationwide Urban Runoff Program,* Pearl River, N.Y.

A report of the work performed on the Long Island segment of the Nationwide Urban Runoff Program by the engineering consultant. It comprises four chapters and five appendices. The chapters discuss contaminant loading factors, control measures, load reduction analysis and plan formulation. The appendices contain much of the information developed in the course of the study. Appendix A contains an annotated history of the project, and a number of memoranda in which several concepts were developed. Appendix B contains summarized data for 26 field sampling efforts from 9/18/80 to 9/8/81. Appendix C is a report on the modeling of the South Shore bays (included in the NURP report as Appendix F). Appendix D is a discussion of the leaching catch basin system at Perry Avenue, Bayville. Appendix E is a compilation of calculations of coliform load removal in 45 South Shore streams.

Mallard, Gail E., 1980, *Microorganisms in stormwater — A summary of recent investigations:* U.S. Geological Survey Open-File Report 80-1198, 18 p.

The major concepts and considerations in microbiological analysis of storm runoff are summarized and documented to provide a basis for use by community planners and water managers. Twenty-seven published reports dating since 1964 are cited.

Versar, Inc., 1980, *Monitoring of Toxic Pollutants in Urban Runoff:* A guidance manual — Interim final report, 85 p.

This report presents a detailed discussion of all aspects of a successful monitoring program to quantify toxic pollutants in urban runoff. These include site selection, flow measurement, water sampling programs and equipment, container selection and cleaning, and sampling collection, preservation and shipment.

Versar, Inc., 1982, Nationwide Urban Runoff Program (NURP): *Special metals project — Report of analytical data (five samples) for the Long Island,* New York NURP study area.

Results of a limited special analysis of five stormwater runoff samples are presented. The samples were collected from a recharge basin draining a major shopping center parking lot during a single storm event and were analyzed for concentrations of 29 metals.

Preceding page blank

Appendix A

Nationwide Urban Runoff Program Participants

Preceding page blank

Nationwide Urban Runoff Program Participants

PROTOTYPE PROJECTS IN THE NATIONWIDE URBAN RUNOFF PROGRAM

Region	Grantee	Project Location	Other Agencies	Receiving Water Type a	b	c	d	e	f	Impacts g	h	i	Average Rainfall (in/yr)	Candidate Best Management Practices j	k	l	m	n	Other
I	Commonwealth of Massachusetts	Lake Quinsigamond, MA			x					x	x	o	46						
	Commonwealth of Massachusetts	Mystic River, MA		o	x	o				x	o	o							swirl concentrator
	New Hampshire Water Supply	Durham, NH				o	x			x	o	o			o	o	o		
II	Long Island Regional Planning Board	Long Island, NY	Suffolk Co., Nassau Co., USGS			o	x			x	o	o	44	o	x			x	permeable sewer
	New York State Department of Environmental Conservation	Lake George, NY	USGS		x						x		35						
	New York State Department of Environmental Conservation	Irondequoit Bay, NY	Monroe Co., USGS	o	x					x	o	o	32		o			o	
III	Washington Council of Governments	Metro Washington, DC		o		o	o			x	o	o	50		x				
	Baltimore Regional Planning Council	Baltimore, MD		o		x				o	x	o	45						
IV	Waccamaw Regional Planning Council	Myrtle Beach, SC	South Carolina Dept. of Health & Environment					x		o	x	o						o	collector/outfall
	North Carolina Department of Economic and Natural Resources	Winston-Salem, NC	USGS	x	o	o				x			44	o		o			
	Tampa Department of Public Works	Tampa, FL	Florida Dept. of Environmental Regulation			x	o			o	x		49						
	Knoxville Metropolitan Planning Commission	Knoxville, TN	TVA, State of Tennessee	o	o	o					x		54						
V	Tri-County Regional Planning Commission	Lansing, MI	Ingham Co.			o				o					x				oversize sewer
	Southeastern Michigan Council of Governments	Oakland County, MI		o	o	o					o				o				runoff ordinance
	Southeastern Michigan Council of Governments	Ann Arbor, MI	Washtanaw Co.			x					o				x			x	
	Illinois Environmental Protection Agency	Champaign-Urbana, IL	Ill. State Water Survey, USGS	o						x				x					
	Northeastern Illinois Planning and Development Commission	Glen Ellyn, IL		o	o						o		34		x				
	Wisconsin Department of Natural Resources	Milwaukee, WI	USGS, Southeastern Wisconsin Regional Planning Commission	x	o	o				x			31	x					
VI	City of Austin	Austin TX	Lower Colorado River Authority		x						o				o				runoff ordinance
	Metroplan	Little Rock, AR		x		o				o	o		50						
VII	Mid-America Regional Council	Kansas City, MO		x		o				o	x		39						

PROTOTYPE PROJECTS IN THE NATIONWIDE URBAN RUNOFF PROGRAM
(Continued)

Region	Grantee	Project Location	Other Agencies	Receiving Water Type								Impacts			Average Rainfall (in/yr)	Candidate Best Management Practices				
				a	b	c	d	e	f	g	h	i	j	k	l	m	n	Other
VIII	Denver Regional Council of Government	Denver, CO	USGS, Adams Co.	o	o	x				o	c		16	o	x			runoff ordinance
	Salt Lake County	Salt Lake City, UT	USGS	o		x				o	x	o	15			x	x	o	canal storage, education
	Sixth District Council of Local Governments	Rapid City, SD	USGS, S. Dakota Dept. of Natural Resources	x						x	o	o			x			
IX	Alameda County Flood Control and Water Conservation District	Castro Valley, CA	USGS	x									22	x				
	State of California	Fresno, CA	Fresno Metropolitan Flood Control District, USGS					x		o	o				x			
X	City of Bellevue	Bellevue, WA	USGS	x	o					x		o		x	x			
	Lane County Council of Governments	Eugene, OR		x	o	o				o	o						o	

LEGEND: x Aspects of program receiving major emphasis. For receiving water, this means an emphasis on monitoring and impact assessment. For BMP's, this means an emphasis on determining control effectiveness and cost.

o Aspects of program receiving less vigorous attention.

NOTE: For some projects, the program to asses BMP's will not be formulated until the completion of the first year's problem assesment effort.

a–Small Stream
b–Lake
c–River
d–Estuary
e–Ocean
f–Groundwater
g–Actual Impairment of Beneficial Use
h–Standards Violation
i–Public Concern
j–Street Sweeping
k–Detention Basins
l–Catch-Basin Cleaning
m–Cross-Connection Elimination
n–Wetlands Treatment

Appendix B

New York State Environmental Conservation Law and Regulations Affecting the Taking of Shellfish

SECTION A: 6NYCRR47

SECTION B: PARAGRAPHS OF STATE ENVIRONMENTAL CONSERVATION LAW AUTHORIZING 6NYCRR47

SECTION A

Part 47, Title 6, of the New York Code of Rules and Regulations, 6NYCRR47, "Certification of Shellfish Lands."

PART 47

CERTIFICATION OF SHELLFISH LANDS

(Statutory authority: Environmental Conservation Law, §§ 11-0105, 11-2301, 13-0307, 13-0311, 13-0319)

Sec.
47.1 Definitions
47.2 General prohibitions
47.3 Examinations of sanitary condition of shellfish lands
47.4 Shellfish hazardous for use as food for human consumption
47.5 Penalties

Historical Note

Part (§§ 47.1-47.5) filed June 3, 1977; amd. filed July 13, 1977, repealed, new filed May 3, 1978 eff. May 3, 1978.

Section 47.1 Definitions. Unless the context otherwise requires, the following terms and their derivatives when used in this Part shall have the following meanings:

(a) Approved means acceptable to the commissioner, based on his determination as to conformance with appropriate standards and/or good public health practices and/or good manufacturing practices.

(b) Coliform group means all of the aerobic and facultative anaerobic gram-negative, non-spore-forming rod-shaped bacteria which will produce gas from lactose when such lactose is incubated for 51 hours or less at 35 degrees Celsius plus or minus 0.5 degrees Celsius.

(c) Commissioner means the Commissioner of Environmental Conservation or his duly authorized representative.

(d) Contamination means any foul, loathsome, dangerous, toxic, abnormal, impure or unsafe substance. Contaminated means the presence of such substance or substances.

(e) Department means the State of New York Department of Environmental Conservation.

(f) Fecal coliform means bacteria of the coliform group which will produce gas from EC medium when such medium is incubated for 26 hours or less at 44.5 degress Celsius plus or minus 0.2 degree Celsius in a water bath.

(g) Harvester or digger means a person who takes shellfish from shellfish lands. Harvest means to take shellfish from shellfish lands.

(h) Hazardous means actually or potentially dangerous to human health. Nonhazardous means not actually or potentially dangerous to human health.

Preceding page blank

(i) Marine district means the waters of the Atlantic Ocean within three nautical miles of the coastline of the State, and all tidal waters within the State, including the Hudson River up to the Tappan Zee Bridge.

(j) MPN means most probable number, which is an estimate of the number of bacteria per 100 milliliters or grams of sample, using laboratory tests and probability tables in a manner endorsed and/or approved by the United States Department of Health, Education and Welfare, Public Health Service, Food and Drug Administration.

(k) Person means any individual, group of individuals, public or private corporation, industry, copartnership, joint-stock company, association, firm, legal entity, trust or estate.

(l) Shellfish means oysters, clams, mussels or scallops, or any edible portion thereof.

(m) Shellfish lands means all tidal or saline waters within the marine district and the lands lying thereunder, including such lands which are exposed at low tide.

(n) Total coliform means bacteria of the coliform group which will produce gas from brilliant green bile lactose broth two percent when such broth is incubated for 51 hours or less at 35 degrees Celsius plus or minus five-tenths (0.5) degree Celsius.

(o) Uncertified shellfish lands means shellfish lands from which, except as otherwise provided pursuant to the Environmental Conservation Law or this Subchapter, the harvesting of shellfish for use as food has been prohibited by commissioner's order.

Historical Note

Sec. filed June 3, 1977; amd. filed July 13, 1977; repealed, new filed May 3, 1978, amds. filed: May 3, 1979; April 29, 1982 eff. April 29, 1982.

47.2 General prohibitions. (a) No person shall fail to comply with the provisions of this Part.

(b) No person shall harvest shellfish for use as food from certified shellfish lands and/or conditionally certified shellfish lands except in compliance with terms of a current order of the commissioner issued pursuant to the Environmental Conservation Law or this Part. Except as otherwise provided pursuant to the Environmental Conservation Law or this Subchapter, no person shall harvest shellfish for use as food and/or other purposes from uncertified shellfish lands if such lands have been designated by a current order of the commissioner issued pursuant to this Part, the Environmental Conservation Law or this Subchapter.

(c) Except as otherwise provided by the Environmental Conservation Law or a provision of this Subchapter, no person shall harvest shellfish from certified shellfish lands and/or conditionally certified shellfish lands without a valid shellfish digger's permit issued by the department.

(d) Nothing herein shall be construed as relieving any person from complying with any applicable Federal, State or local law or rule or regulation.

Historical Note

Sec. filed June 3, 1977; amd. filed July 13, 1977; repealed, new filed May 3, 1978 eff. May 3, 1978

47.3 Examinations of sanitary condition of shellfish lands. (a) Certified shellfish lands.

(1) The department shall periodically examine shellfish lands to determine the sanitary condition thereof. Following an examination, the department shall on the basis of criteria contained in paragraph (2) of this subdivision determine which of the examined shellfish lands are of such sanitary condition that shellfish may be taken therefrom for use as food. Lands that meet such criteria shall be designated, by commissioner's order, certified shellfish lands. Lands which do not meet such criteria shall be designated, by commissioner's order, uncertified shellfish lands. At any time particular certified shellfish lands may be redesignated by commissioner's order as uncertified shellfish lands if such lands no longer meet the criteria contained in paragraph (2) of this subdivision. The department, annually, and as often as it deems necessary, shall cause a notice describing certified shellfish lands and uncertified shellfish lands to be published in a newspaper in the county in which such lands are located.

(2) Waters overlying certified shellfish lands shall:

(i) not have received hazardous amounts of contamination, which may have been occasioned by precipitation, storm water runoff, malfunctionings of waste water treatment facilities, spills of hazardous materials or other similar events;

(ii) not be so contaminated with fecal material, radionuclides or industrial wastes that shellfish from such lands might be hazardous for use as food; and

(iii) have, when samples are collected from those portions of the lands most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions: a median total coliform MPN per 100 milliliters of sample of 70 or less; and ordinarily not more than 10 percent of the samples shall have a total coliform MPN per 100 milliliters of sample in excess of 330 when a multiple dilution fermentation tube test is used which examines three 10-milliliter sample portions, three one-milliliter sample portions and three one-tenth (0.1) milliliter sample portions; and ordinarily not more than 10 percent of the samples shall have a total coliform MPN per 100 milliliters of sample in excess of 240 when a multiple dilution fermentation tube test is used which examines five 10-milliliter sample portions, five one-milliliter sample portions and five one-tenth (0.1) milliliter sample portions; and ordinarily not more than 10 percent of the samples shall have a total coliform MPN per 100 milliliters of sample in excess of 230 when a multiple dilution fermentation tube test is used which examines five 10-milliliter sample portions, five one-milliliter sample portions, five one-tenth (0.1) milliliter sample portions and five one-hundredth (0.01) milliliter sample portions; or

(iv) have, when samples are collected from those portions of the lands most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions: a median fecal coliform MPN per 100 milliliters of sample of 14 or less; and ordinarily not more than 10 percent of the samples shall have a fecal coliform MPN per 100 milliliters of sample in excess of 49 when a multiple dilution fermentation tube test is used which examines three 10-milliliter sample portions,

three one-milliliter sample portions and three one-tenth (0.1) milliliter sample portions; and ordinarily not more than 10 percent of the samples shall have a fecal coliform MPN per 100 milliliters of sample in excess of 43 when a multiple dilution fermentation tube test is used which examines five 10-milliliter sample portions, five one-milliliter sample portions and five one-tenth (0.1) milliliter sample portions.

(3) The commissioner, in his discretion, may designate by order particular shellfish lands as certified shellfish lands if detailed shoreline surveys or sanitary surveys of such lands indicate that the coliform bacteria are not of fecal origin; and the commissioner, in his discretion, may designate by order particular uncertified shellfish lands as certified shellfish lands during seasons when such lands meet the criteria contained in paragraph (2) of this subdivision. At any time particular certified shellfish lands may be redesignated by commissioner's order as uncertified shellfish lands, if such lands no longer meet the criteria contained in paragraph (2) of this subdivision.

(b) Conditionally certified shellfish lands. (1) The department shall regularly examine the sanitary condition of appropriate uncertified shellfish lands which it has determined are likely to be periodically nonhazardous for purposes of harvesting shellfish for use as food. Following an examination the department shall, on the basis of criteria contained in paragraph (2) of this subdivision, determine which of such lands are in such nonhazardous condition that shellfish may be taken therefrom for use as food. Shellfish lands that meet such criteria may be designated by commissioner's order as "conditionally certified shellfish lands". At any time, particular conditionally certified shellfish lands may be redesignated by commissioner's order as "uncertified shellfish lands" if such lands no longer meet the criteria contained in paragraph (2) of this subdivision. Such orders shall state with specificity the boundaries of the lands so "conditionally certified" or "uncertified" by using reference points taken from appropriate United States National Oceanic and Atmospheric Administration nautical charts or using reference points such as local landmarks or local names or using reference points such as buoys or monuments when such buoys or monuments have been installed and/or maintained in a manner approved by the commissioner. Public notice of such orders shall be given by posting in the State of New York Department of Environmental Conservation's Region No. 1 Office, Building 40, State University of New York, Stony Brook, N. Y. 11794; by announcements by radio stations, when deemed necessary by the commissioner; by a telephone system operated by the department and/or by a cooperating political subdivision of the State of New York; and by other means approved by the commissioner.

(2) Water overlying conditionally certified shellfish lands shall:

(i) not have received hazardous amounts of contamination, which may have been occasioned by precipitation, storm water runoff, malfunctionings of waste water treatment facilities, spills of hazardous materials or other similar events, for a period of at least seven days immediately prior to the designation of such lands as conditionally certified and shall not receive such contamination during the period that such lands are so designated;

(ii) not be so contaminated with fecal material, radionuclides or industrial wastes that shellfish from such land might be hazardous for use as food during the period that such lands are designated as conditionally certified; and

(iii) have, during the period that such lands are designated as conditionally certified, a median total coliform MPN per 100 milliliters of sample of 70 or less; and ordinarily not more than 10 percent of the samples shall have a total coliform MPN per 100 milliliters of sample in excess of 330 when a multiple dilution fermentation tube test is used which examines three 10-milliliter sample portions, three one-milliliter sample portions and three one-tenth (0.1) milliliter sample portions; and ordinarily not more than 10 percent of the sample shall have a total coliform MPN per 100 milliliters of sample in excess of 240 when a multiple dilution fermentation tube test is used which examines five 10-milliliter sample portions, five, one milliliter sample portions and five one-tenth (0.1) milliliter sample portions and ordinarily not more than 10 percent of the samples shall have a total coliform MPN per 100 milliliters of sample in excess of 230 when a multiple dilution fermentation tube test is used which examines five 10-milliliter sample portions, five one-milliliter sample portions and five one-tenth (0.1) milliliter sample portions and five one-hundredth (0.01) milliliter sample portions.

(c) Samples of water, shellfish and other materials shall be collected and examined in a manner endorsed and/or approved by the United States Department of Health and Human Services, Public Health Service and Food and Drug Administration. Laboratories engaged in the bacteriological examination of water, shellfish and other materials shall have received and shall maintain a satisfactory evaluation by the United States Department of Health and Human Services, Public Health Service and Food and Drug Administration in order for results of such examinations to be acceptable to the department.

Historical Note

Sec. filed June 3, 1977; amd. filed July 13, 1977; repealed, new filed May 3, 1978; amds. filed: May 3, 1979; Oct. 28, 1980; March 16, 1981 as emergency measure, expired 60 days after filing; April 29, 1982 eff. April 29, 1982. Added (a)(2)(iv) and (a)(3).

47.4 Shellfish hazardous for use as food for human consumption. When the commissioner determines that shellfish might be hazardous for use as food for human consumption, he shall take such action as he deems necessary to protect the public health and welfare. The commissioner may prohibit shellfishing activities such as, but not limited to, the harvesting, shucking, processing, packing, transporting, selling, storing and microbiological cleansing of shellfish for use as food. The commissioner may advise the general public, the shellfish industry and public health officials that shellfish might be hazardous for use as food.

Historical Note

Sec. filed June 3, 1977; amd. filed July 13, 1977 repealed, new filed May 3, 1978 eff. May 3, 1978.

47.5 Penalties. Any person violating any provision of this Part shall be subject to the penalties prescribed in the Environmental Conservation Law.

Historical Note

Sec. filed June 3, 1977; amd. filed July 13, 1977; repealed, new filed May 3, 1978 eff. May 3, 1978.

SECTION B

Paragraphs of the New York State Environmental Conservation Law (as ammended Feb. 12, 1973) that authorize Part 47, Title 6, of the New York Code of Rules and Regulations, 6NYCRR47.
Exerpts from McKinney's Consolidated Laws of New York (Annotated), Book 17½, "Environmental Conservation Law," as ammended, Feb. 12, 1973:—

Para. 11-0105.	Pages 156-8.
Para 11-2301.	Pages 363/4.
Para. 13-0307.	Page 375.
Para 13-0311.	Page 378.
Para 13-0319.	Pages 382/3.

Note 1

Source of Section

Conservation Law of 1911, c. 647, § 151, added L.1955, c. 630, § 1; and repealed by L.1972, c. 664, § 5. Said Conservation Law § 151 derived from Conservation Law of 1911, § 150, added L.1938, c. 40, § 1; and repealed by L.1955, c. 630, § 1.

Library References

Fish ⇐1. C.J.S. Fish §§ 1, 2.
Game ⇐1. C.J.S. Game §§ 2, 3.

Notes of Decisions

Constitutionality 1
Indian reservations 4
Ownership 2
Protection and regulation 3

---

1. Constitutionality

"It is not to be doubted that the power to preserve fish and game within its borders is inherent in the sovereignty of the state (Geer v. Connecticut, 16 S.Ct. 600, 161 U.S. 519, 40 L.Ed. 793; Ward v. Race Horse, 16 S.Ct. 1076, 163 U.S. 504, 507, 41 L.Ed. 244), subject of course to any valid exercise of authority under the provisions of the Federal Constitution." People of State of New York ex rel. Kennedy v. Becker, 1915, 36 S.Ct. 705, 241 U.S. 556, 60 L.Ed. 1166.

The original ownership of wild game is in the state, and the preservation thereof is a lawful and valid exercise of the police power. Geer v. Connecticut, 1896, 16 S.Ct. 600, 161 U.S. 519, 40 L.Ed. 793. See, also, McCready v. Virginia, 1876, 94 U.S. 391, 4 Otto. 391, 24 L.Ed. 248; Holyoke Co. v. Lyman, 1872, 15 Wall. 500, 82 U.S. 500, 21 L.Ed. 133; Dieterich v. Fargo, 1909, 194 N.Y. 350, 87 N.E. 518, 22 L.R.A.,N.S., 696; People v. Hesterberg, 1906, 184 N.Y. 126, 76 N.E. 1032, 128 Am.St.Rep. 528, 3 L.R.A.,N.S., 163; People v. Bootman, 1904, 180 N.Y. 1, 72 N.E. 505; Lawton v. Steele, 1890, 119 N.Y. 226, 23 N.E. 878, 16 Am.St.Rep. 813, 7 L.R.A. 134, affirmed 14 S.Ct. 499, 152 U.S. 133, 38 L.Ed. 385; Rockefeller v. Lamora, 1903, 85 App.Div. 254, 83 N.Y.S. 289; People v. Cone, 1900, 33 Misc. 393, 67 N.Y.S. 624.

The preservation and regulation of wild game is a lawful and valid exercise of the police power by the state. Aber v. State, 1952, 202 Misc. 808, 109 N.Y.S.2d 815, appeal dismissed 283 App.Div. 916, 129 N.Y.S.2d 922.

2. Ownership

A reservation in a deed of the right to fish, in favor of a stranger to the conveyance, is ineffectual to convey to such stranger any estate or interest whatsoever in the lands therein described as against a subsequent purchaser in good faith and for a valuable consideration, whose conveyance has been recorded. Tuscarora Club v. Brown, 1915, 215 N.Y. 543, 109 N.E. 597.

The game and fish within the boundaries of the state belong to the people in their unorganized capacity; there is no property, in living wild animals and only as the law permits their capture is there a right of property in them after they are caught or killed. People v. Bootman, 1904, 180 N.Y. 1, 72 N.E. 505.

In this country fish running at large are ferae naturae, and while in their natural element, unconfined, are the public property of all the people of the state in common, and no person can acquire property therein, divested of the rights of others, except by taking and reducing them to actual possession; and while an individual may thus acquire a qualified property therein, yet if the fish escape and return to the river and are again at large they become public property, and subject to appropriation by the first person who takes

them. In re Fishway, 1909, 131 App. Div. 403, 115 N.Y.S. 745. See, also, People v. Doxtater, 1894, 75 Hun 472, 27 N.Y.S. 481, affirmed 147 N.Y. 723, 42 N.E. 724.

The people of the state have as an easement in the streams the right to have fish inhabit its waters and freely pass to their spawning beds and multiply, and the right to take and use such fish for food, subject to such regulations as the legislature may prescribe; and no riparian proprietor upon a stream has the right to obstruct the free passage of the fish to the detriment of other riparian proprietors or of the public. In re Fishway, 1909, 131 App.Div. 403, 115 N.Y.S. 745.

Fish and game are migratory, and those which may now be on private lands may quickly change their location to public lands and public waters. No man owns wild game or fish even though they be on his land, unless he has reduced them to his possession by capture. If they wander from his premises to those of the public or another, he may not complain of their taking. In public waters and on public lands, this right is open to all alike, and no individual right is trespassed upon by so doing. Fish, especially, form a large source of food supply, and those which propagate upon private property and migrate to public waters may constitute a considerable proportion. Rockefeller v. Lamora, 1903, 85 App.Div. 254, 83 N.Y.S. 289.

Even a fee title of the land under the waters of a lake, and the exclusive right of fishing therein, does not confer upon the holder thereof the ownership of the fish in the lake, and property in them does not vest until they have been reduced to possession so far established, by the aid of nets or other means, that they cannot escape. People v. Doxtater, 1894, 75 Hun 472, 27 N.Y.S. 481, affirmed 147 N.Y. 723, 42 N.E. 724.

One can gain no exclusive title to the waters of streams or lakes by adverse or continuous user, as the waters of the state are common to all, and the title of the state is held in trust for the people, and all rights exercised in the waters of the state are to be enjoyed in common. Hooker v. Cummings, 1822, 20 Johns. 90, 11 Am.Dec. 249. See, also, Slingerland v. International Contracting Co., 1901, 169 N.Y. 60, 61 N.E. 995, 56 L.R.A. 494.

3. Protection and regulation

The general right of the government to protect wild animals is too well established now to be called in question. Their ownership is in the state in its sovereign capacity, for the benefit of all the people. Their preservation is a matter of public interest. They are a species of natural wealth which without special protection would be destroyed. Everywhere and at all times governments have assumed the right to prescribe how and when they may be taken or killed. Barrett v. State, 1917, 220 N.Y. 423, 116 N.E. 99.

The method of affording protection to game is within the discretion of the legislature. "It may provide a closed season for the taking of game, and may prohibit the possession or sale of game during that season. It may close the game market throughout the state during the period of prohibition, in order to remove temptation from poachers and pot-hunters, who are not apt to run the risk of taking game out of season if they cannot sell it. To do this effectively, it may be necessary to close the market as to game taken without the state, as well as within, for there are no marks by which birds killed in Michigan can be distinguished from those killed in New York. When enacting a game law the legislature may provide for its ready enforcement, not simply by making the possession of game during the closed season presumptive evidence of a violation of the statute, but it may go farther and, in order to prevent evasion, fraud and perjury, may prohibit the possession of game in this state during the closed season, even if it was taken in another state and brought here during the open season." People v. Bootman, 1904, 180 N.Y. 1, 72 N.E. 505.

It is to the interest of the state that neither game nor fish should be wasted or destroyed and that both should be carefully protected, especially during the breeding season. Without protection the fish and game will soon disappear and the people thus be deprived of an important source of food supply, as well as a delightful recreation which promotes health and prolongs life. The protection of game falls within the legitimate exercise of the police power, because it is directly connected with the public welfare, which is promoted by the preservation and injured by the destruction of so useful an article of food, free at the proper time to all the people of the state. Id.

The right of the legislature to regulate the taking of fish from the streams of the state, and even from private waters, has been exercised from the earliest period of the common law, and has long been established. Lawton v. Steele, 1890, 119 N.Y. 226, 23 N.E. 878, 16 Am.St.Rep. 816, 7 L.R.A. 134, affirmed 14 S.Ct. 498, 152 U.S. 133, 38 L.Ed. 385. See, also, In re Fishway, 1909, 131 App. Div. 403, 115 N.Y.S. 745; People v. Doxtater, 1894, 75 Hun 472, 27 N.Y.S. 481, affirmed 147 N.Y. 723, 42 N.E. 724; Hooker v. Cummings, 1822, 20 Johns. 90, 11 Am.Dec. 249.

That they may not be disturbed in propagation, the regulation of the manner and time of the killing of fish and game is a proper subject of legislative action. Rockefeller v. Lamora, 1903, 85 App.Div. 254, 83 N.Y.S. 289.

The right to the state to exercise dominion and control over its territory extends to and embraces the lands which lie under the waters within its jurisdiction, and under its proprietary rights therein it may regulate and control the public right of fishery, and also protect private rights of property therein, so far as they may be properly recognized in connection with the public enjoyment; and this right to exercise control over that part of its territory which lies below high-water mark is subject only to the exception that its legislation in respect thereto shall not come in conflict with the laws of the United States in its admiralty jurisdiction or otherwise. Colon v. Lisk, 1897, 13 App.Div. 195, 43 N.Y.S. 364, affirmed 153 N.Y. 188, 47 N.E. 302, 60 Am.St.Rep. 609.

The legislature has power to make regulations for the protection and preservation of fish within the waters of the state for the common enjoyment of its citizens, and this power is not limited to navigable waters, or otherwise public waters, but includes private waters (waters flowing over lands subject to private ownership) where fish spawn, live and through which they may migrate to and from public fishing grounds of the state. Such private waters, for the purpose of applying laws for the protection and preservation of fish, are to be deemed waters of the state, and coming within the regulating power of the state concerning the fish therein. 1911, Op.Atty.Gen. 251.

4. Indian reservations

The Indians of the state are bound to obey the game laws, notwithstanding a reservation in conveyances made by them of the right to fish and hunt, and although a violation thereof occurs within the limits of an Indian reservation. People v. Pierce, 1896, 18 Misc. 83, 41 N.Y.S. 858.

Under former section 175 of the Conservation Law the laws relating to the taking of game and fish were applicable within the Seneca Indian reservations. 1927, Op.Atty.Gen. 320.

TITLE 23—ADMINISTRATION OF FISH AND WILDLIFE LAW

Sec.

11-2301. Orders of the department.
11-2303. Disposition of moneys.
11-2305. Sale of trees, timber and other products.
11-2307. Cooperative agreements with towns, villages and counties concerning lands dedicated to conservation purposes.

§ 11-2301. Orders of the department

1. a. Rules and regulations made by the department as provided in the Fish and Wildlife Law shall be made by order.

b. All orders shall be signed by the commissioner or deputy commissioner and shall be entered in a minute book.

c. Orders required to be certified before filing, as provided in subdivision 2, shall be certified by an officer of the department designated by the commissioner.

2. a. A copy of each order made pursuant to the Fish and Wildlife Law shall be filed in the office of the Department of State before it becomes effective.

b. A certified copy of each of the following orders shall be filed in the office of the county clerk of each county affected by its terms except when the order is made pursuant to section 11-2101 to regulate use of public hunting, trapping or fishing grounds or other lands or waters owned, leased or acquired by the state and made available to the department for use by the department, or when the order regulates use of specially licensed or registered premises:

(1) orders fixing open seasons or bag limits for any wild game other than migratory game birds; (2) orders permitting taking of beaver, fisher or otter by holders of trapping licenses; (3) orders fixing open seasons or minimum size limits for the taking of any fish by angling; (4) any order closing any waters to the taking of fish by angling, or to the taking of insects, or limiting the type of bait that may be used, or restricting use of devices otherwise permitted in angling; (5) any other order specified in this subdivision.

c. The following orders shall also be published in a newspaper in each county affected:

(1) Order under section 11-0311, giving protection or additional protection to wild game or fish;

(2) Order under section 11-0313, closing waters to the taking of fish because of low water levels brought on by drought.

d. The following orders shall be so filed in the respective county clerk's office and so published when required within the times specified:

(1) Order under subdivision 6 of section 11-0903 opening a tract of land in a Wilderness Hunting Area to the taking of antlerless deer: not later than August 1;

(2) Order under subdivision 5 of section 11-0903, fixing open seasons in the Southern Zone for deer of either sex: September 1;

(3) Order under subdivision 1 of section 11-1103, permitting the taking of beaver, fisher or otter by holders of trapping licenses: before the effective date of the order;

(4) Order under section 11-1103, fixing open seasons for muskrat and mink: before the effective date of the order;

(5) Order under section 11-0313, closing waters to taking of fish because of low water levels brought on by drought: at least five days before the order takes effect;

(6) Orders amending, correcting or rescinding an order described in this subdivision: before the effective date of the order.

(7) Orders under subdivision 7 of section 11-0903, fixing special seasons for deer of either sex: before effective date of the order.

(8) Orders under subdivision 9 of section 11-0903, fixing open seasons for deer of either sex in Westchester County: December 1;

e. Every other order described in paragraph b or paragraph c shall be so filed, and so published where required, at least fifteen days before it takes effect.

L.1972, c. 664, § 2.

Source of Section

Conservation Law of 1911, c. 647, § 390, added L.1955, c. 630, § 1; amended L.1956, c. 29, §§ 41, 42; L.1956, c. 183, § 2; L.1956, c. 344, § 1; L.1957, c. 66, § 38; L.1959, c. 377, § 8; L.1959, c. 738, § 4; L.1969, c. 652, § 17; L.1970, c. 189, §§ 12, 13; and repealed by L.1972, c. 664, § 5.

Library References

Fish ⇐11. C.J.S. Fish § 37.
Game ⇐6. C.J.S. Game § 9.

§ 13–0307. Sanitary surveys

1. The department periodically shall examine all shellfish lands within the state to ascertain the sanitary condition thereof.

2. The department, following an examination, shall certify which shellfish lands and the product thereon are in such sanitary condition that shellfish thereon may be taken for use as food. Such lands shall be designated as certified areas, and all other shellfish lands as uncertified areas.

3. The department, annually, and as often as it deems necessary, shall publish in a newspaper in the county in which such lands are located, a notice containing a description of both certified and uncertified areas.

L.1972, c. 664, § 2.

Source of Section

Conservation Law of 1911, c. 647, § 305, added L.1955, c. 630, § 1; amended L.1959, c. 544, § 1; and repealed by L.1972, c. 664, § 5.

Notes of Decisions

1. Certification of lands

State Conservation Commission has authority to certify those lands from which shellfish may be taken for use as food. De Roche v. Osborne, 1942, 179 Misc. 589, 37 N.Y.S.2d 348.

An attack on order of State Conservation Commission and Board of Health of City of New York closing certain bays to clam digging for reasons of public health, as unreasonable, because New Jersey had not closed clam beds in portion of same bays within its jurisdiction and that clams dug therefrom were being sold in New York market, failed upon showing that before hearing of petition New Jersey had taken same action. Id.

§ 13–0311. Digger's permit to take shellfish for commercial purposes; when not required

1. Subject to the provisions of this article, a person who has been a resident of this state for six months immediately prior to the date of application may take shellfish from under water lands in the state for commercial purposes upon first obtaining a digger's permit from the department, provided, however, that the application for such permit by a person sixteen years of age or under shall be signed by his parent or legal guardian, who shall thereby consent to the issuance of the permit.

2. The department shall prescribe and furnish forms for application for such permit.

3. The fee for such permit shall be seven dollars and fifty cents. Such permit shall expire on December 31 of the year of issue. If it appears in the public interest, the department may, after hearing held on ten day's notice, suspend or cancel such permits, except that in case of a taking from an uncertified area such suspension or cancellation may be without prior notice.

4. The holder of such permit shall not ship or sell shellfish except to a holder of a valid Class A, D, or G shipper's permit who has a place of business in the township or borough in which such shellfish were harvested, without first obtaining a shipper's permit as provided in subdivision 1 of section 13–0315.

5. Subject to the provisions of this article, a person may, without permit, take from public certified areas not to exceed two pecks of shellfish in any one day for his own or his family use.

6. The holder of such digger's permit shall carry the permit assigned to him on his person while engaged in the permitted activities, and the failure by such holder to exhibit his permit to any shellfish inspector, conservation enforcement officer, health official, peace officer or magistrate shall be presumptive evidence that no valid digger's permit has been issued to him.

L.1972, c. 664, § 2.

Source of Section

Conservation Law of 1911, c. 647, § 307, added L.1955, c. 630, § 1; amended L.1959, c. 544, § 3; L.1962, cc. 192, 194; L.1963, c. 444, §§ 1, 2; and repealed by L.1972, c. 664, § 5. Said Conservation Law § 307 derived in part from former section 307 of the Conservation Law of 1911, added L. 1942, c. 105, § 1; amended L.1946, c. 490; and repealed by L.1955, c. 630, § 1.

§ 13-0319. Shellfish regulations by order of department

The department may by order make regulations pursuant to section 11-2301 with respect to the harvesting, transplanting, relaying, receiving, possessing, transporting, importing, exporting, processing, buying, selling of or otherwise trafficking in shellfish; the labeling or tagging thereof; the keeping of records of shellfish received, transported and distributed; the construction, operation and maintenance of all shellfish handling, processing and distributing establishments, including facilities and equipment and the cleaning, cleansing and water storage of shellfish. The provisions of this section relating to transplanting and relaying include but are not limited to the removal of shellfish from uncertified growing areas and transplanting to certified areas for subsequent harvest for market purposes and transplanting of scallops pursuant to paragraph a of subdivision 2 of section 13-0327. Such regulations shall be drawn in such a manner as to provide adequate sanitary control over all shellfish offered for sale and distribution in the state. Such regulations shall not be less restrictive than the minimum requirements of any federal agency regulating the inter-state shipment of shellfish.

L.1972, c. 664, § 2.

Source of Section

Conservation Law of 1911, c. 647, § 311, added L.1955, c. 630, § 1; amended L.1959, c. 544, § 7; and repealed by L.1972, c. 664, § 5. Said Conservation Law § 311 derived from a former section 311 of the Conservation Law of 1911, added L.1942, c. 105, § 1; and repealed by L.1955, c. 630, § 1.

Notes of Decisions

Chlorination plants 2
County regulations 1
Inspection of fish market 3

---

1. County regulations

The provisions of the state law should be interpreted merely as conferring the power on boards of supervisors to enact laws containing restrictions and prohibitions additional to such as are contained in the general state laws or in special or local state laws which it may be seen are not intended to and do not cover the whole subject, or take it exclusively unto themselves, and not as laws conflicting with or overriding state legislation on the same subject. People v. Fish, 1895, 89 Hun 163, 34 N.Y.S. 1013.

The board of supervisors of a county have power to provide for the protection and preservation, subject to the laws of the state, of wild animals, birds, game, fish and shellfish, within the county, and to prescribe and enforce the collection of penalties for the violation thereof. 1902, Op.Atty. Gen. 298. See, also, 1892, Op.Atty. Gen. 250.

2. Chlorination plants

The Conservation Department could issue permits under subdivision 5 of former section 305 of the Conservation Law to operators of proposed chlorination plants, under which the latter could be constructed according to plans and specifications approved by the department and thereafter operated under its supervision, and could issue permits to clam diggers, under which clams could be taken from uncertified areas, to be sold only to the operators of such plants, provided such permits were issued under general rules and regulations so framed as to prevent the creation of a monopoly. 1943, Op. Atty.Gen. 229.

3. Inspection of fish market

Conservation department officers had right to enter fish market premises and conduct inspection to determine sanitary conditions. People v. Borregine, 1966, 52 Misc.2d 996, 276 N.Y.S.2d 734.

Conservation officers who were rightfully on fish market premises, under their right to inspect sanitary conditions, could arrest proprietor and seize contraband shellfish, upon observing that shellfish containers did not have labels or tags required by law. Id.

Appendix C

Microogranisms in Stormwater
A Summary of Recent Investigations

Gail E. Mallard
U.S. Geological Survey
Open-File Report 80-1198

MICROORGANISMS IN STORMWATER — A SUMMARY OF RECENT INVESTIGATIONS

ABSTRACT

The major concepts and considerations in microbiological analysis of storm runoff are summarized and documented to provide a basis for use by community planners, water managers, and others interested in studies of stormwater. Twenty-seven published reports dating since 1964 are cited.

All storm runoff contains a variety of bacteria, including total coliforms, fecal coliforms, and fecal streptococci, which are derived from the land over which the water flows. Most of the total coliforms are native soil organisms, whereas the fecal coliforms and fecal streptococci originate from the feces of wild and domestic animals. Urban runoff has been reported to contain pathogenic organisms, but this probably presents little direct threat to human health because the runoff is not ingested. Runoff water can, however, have other negative effects such as contamination of surface water, which may result in beach closures, or contamination of shellfish. This type of contamination is generally of short duration because indicator bacteria and pathogens die out rapidly in the aquatic environment. Similarly, bacteria and viruses deposited on soil by stormwater are inactivated by drying, competition from soil microflora, and a variety of other processes.

Every storm producing runoff is unique in the number and type of microorganisms because these vary from site to site, from storm to storm, and during the course of the storm. Stormwater to be examined for microorganisms must be collected in sterile containers and processed immediately.

INTRODUCTION

Any attempt to find microorganisms in stormwater generally will meet with success. Bacteria and viruses are normal inhabitants of soil, water, human and animal skin and gut, plant surfaces, and indeed almost every place on earth. Only certain extremely hostile environments and the internal tissues of plants and animals are free of microorganisms. Stormwater running over the land surface will inevitably become contaminated, but this should not be a cause for concern unless it threatens human health or well-being. Does stormwater present a serious threat? Unfortunately, no unequivocal answer can be given. Stormwater carrying microorganisms may enter a drinking-water source and cause an outbreak of disease, or it may lead only to the temporary shutdown of recreation facilities such as beaches. Depending on local conditions, the study of microbial contamination of runoff may be of real importance to a community or it may be of only academic interest.

Purpose and Scope

This summary presents general information gained from recent investigations and describes problems that may arise in future investigations. It is hoped that this information will be of value in planning studies that involve microorganisms in stormwater. This report was prepared for the National Urban Runoff Program in cooperation with the Long Island Regional Planning Board.

BASIC CONCEPTS IN MICROBIOLOGY

All scientific and technical fields have concepts, procedures, assumptions, and terminology that are unfamiliar to the nonspecialist. Although many of the terms and concepts of microbiology are familiar to the general public, the exact meanings and limitations may be poorly understood. For this reason, the main discussion of microorganisms in storm runoff is preceded by a brief introduction to some of the principles of microbiology. A glossary of biological and microbiological terms is provided by Greeson and others (1977).

Indicator Organisms

Water that has been polluted by human sewage is hazardous because several diseases are transmitted via the *fecal-oral* route, such as *typhoid, cholera, dysentery, an[illegible]patitis.* When presented with a water sample that is suspect, the microbiologist typically does not try to isolate and identify the pathogens, but instead determines numbers of *indicator* organisms — total coliforms, fecal coliforms, and fecal streptococci. These bacteria are known as *indicator organisms* because they indicate the presence of sewage and ideally are correlated with the number of pathogens in a water sample.

The growth characteristics and metabolic reactions of the indicator organisms have been investigated for many years, and relatively easy and straightforward methods for their detection and enumeration are available (American Public Health Association, 1975; Greeson and others, 1977). In con-

trast, methods for detection of pathogens are complicated, tedious, and time consuming.

In addition to being easier to isolate and study in the laboratory than pathogens, indicators are used because water contaminated by human waste will typically contain many more of these organisms than pathogens. Indicator organisms are present at relatively high levels in all members of the population and are being shed at all times. In contrast, only a few clinical cases and carriers will be shedding pathogens at any given time.

Most of the characteristics of an ideal indicator organism are listed in *Drinking Water and Health* (National Research Council, 1977, p. 71) and are quoted below:

1. Applicable to all types of water.
2. Present in sewage and polluted waters when pathogens are present.
3. Number is correlated with the amount of pollution.
4. Present in greater numbers than pathogens.
5. No aftergrowth in water.
6. Greater survival time than pathogens.
7. Absent from unpolluted waters.
8. Easily detected by simple laboratory tests in the shortest time consistent with accurate results.
9. Has constant characteristics.
10. Harmless to man and animal.

Although no organism or group of organisms is a perfect indicator, *coliforms* are ideal in most ways and have been used by water microbiologists and others concerned with the public health for many years. The U.S. Environmental Protection Agency's safe drinking-water standards are written in terms of coliforms rather than pathogens (American Public Health Association, 1975) as are standards for recreational waters. As recently as 1977, the use of coliforms as indicators of fecal contamination was endorsed by the Safe Drinking Water Committee of the National Research Council (1977). Yet, the popularity of coliforms as an indicator does not preclude critical reviews of their use (Dutka, 1973) or suggestions that other organisms or groups would provide more accurate determinations (Carberry and Stapleford, 1979). Additionally, continuing efforts are being made by many investigators to refine the methods used to detect indicator organisms.

The effectiveness of total coliforms, fecal coliforms, and fecal streptococci as indicators of viral contamination is particularly suspect. Several reports indicate that bacterial indicators are inadequate predictors of viruses in ground water (Marzouk and others, 1979; Vaughn and others, 1978) as well as fresh and marine surface waters (Vaughn and others, 1979). This lack of a reliable indicator for enteroviruses presents a serious problem because detection of viruses in water samples requires expensive and time-consuming procedures. Studies of viruses in the environment are, however, becoming more commonplace, and methods for their detection and enumeration are being improved.

The use of indicator organisms in stormwater-runoff studies may pose a special problem. Most of the fecal coliforms and fecal streptococci in stormwater are derived from animal feces, so that the level of these indicator organisms may be high at all times, regardless of the number of pathogens in the water sample. Olivieri and others (1977) found little or no correlation between indicator bacteria and either pathogenic bacteria or enteric viruses in storm samples.

Ratios of Fecal Coliforms to Fecal Streptococci

Aside from the question of the reliability of indicator organisms, a significant question remains unanswered—how is human fecal contamination differentiated from other fecal contamination? Since fecal material from many warm-blooded animals contains coliforms and streptococci, the presence of these groups does not mean that human waste was the source of contamination. Geldreich and Kenner (1969) approached this problem by examining feces from various warm-blooded animals (included humans), domestic wastewater, stormwater, food-processing wastes, agricultural waters, and recreational waters. They concluded that the ratio of fecal coliforms to fecal streptococci (FC:FS) in human feces and in water polluted with human waste is always greater than 4.0, whereas the ratio of fecal coliforms to fecal streptococci in feces from farm animals, cats, dogs, and rodents, and in separate stormwater systems and farmland drainage, is less than 0.7.

Although the ratio of fecal coliforms to fecal streptococci in a water sample gives some indication of the source of the contamination, these ratios must be interpreted with caution. First, the water samples must be taken near the source of contamination because once the organisms have entered the receiving body of water, variables such as temperature, pH, metal concentration, nutrient availability, and other environmental factors will alter the interrelationship between the two indicator systems. McFeters and others (1974) investigated the question of survival of indicator bacteria in natural waters and found that the initially high FC:FS ratio of human sewage decreased with time, whereas the initially low ratio for waste from domestic livestock increased. This reinforces the advice given by Geldreich and Kenner (1969, p.R349) that *the use of a ratio relationship for stream samples would be valid only during the initial 24-hour travel downstream from point of pollution discharge into the receiving stream.*

Even if used correctly, the FC:FS ratio should not be regarded as a magic number, especially for samples that contain water from a mixture of nonpoint sources. For example, if most of the contamination in a sample were from nonhuman sources, a small amount of human sewage might not be sufficient to shift the overall ratio upward enough to cause concern. As a result, the presence of human pathogens in the human sewage would be masked by the indicator ratio characteristic of animal waste, and a real danger would go undetected.

MICROORGANSIMS IN STORMWATER

Bacterial Load of Stormwater

Rainwater contains very few bacteria before it reaches the ground. Geldreich and others (1968) collected rainwater from 49 storms in sterile collectors and tested for total coliforms, fecal coliforms, and fecal streptococci. In 42 of the samples, counts of these bacteria were less than one organism per 100 mL; in the remaining seven samples, total coliform densities ranged between 1 and 92 per 100 mL. When this *contaminated* rainwater was filtered and the filter examined microscopically, the authors observed soil particles and insect and vegetation fragments, which they believed were the source of the bacteria. Whenever rainwater comes in contact with land, it becomes contaminated with bacteria. Counts of total coliforms, fecal coliforms, and fecal streptococci in stormwater, compiled from several references (Table 1), range as follows: 10^3 to 10^5 total coliforms per 100 mL, 10^2 to 10^4 fecal coliforms per 100 mL, and 10^2 to 10^5 fecal streptococci per 100 mL.

Sources of Bacteria in Stormwater

Geldreich and others (1968) examined 843 stormwater samples and observed that fecal coliforms constituted an average of 8.6 percent of the median total coliforms present. After examining over 7,000 separate strains of coliforms and determining their physiological type, they concluded that the remaining 91.4 percent of the total coliforms came from the soil. The distribution of strains was found to be the same in soil, surface waters, and stormwater. This exhaustive analysis leaves little doubt that most total coliforms in stormwater are native soil organisms that are washed off soil particles by water running over the land surface.

If most of the total coliforms come from the soil, what is the source of the other two pollution indicators—fecal coliforms and fecal streptococci? By definition these are contributed by warm-blooded animals. Because the ratio of fecal coliforms to fecal streptococci in urban stormwater is usually much less than 1 (see Table 1), it is assumed that most of the bacteria in stormwater are of nonhuman origin. In an urban environment, this pollution is most likely due to fecal material from dogs, cats, rodents, and other small animals, whereas in rural areas, larger domestic animals would make a significant contribution. In either case the amount of waste generated by animals should not be underestimated. For example, Geldreich (1976, p. 361) cites an estimate that *the 500,000 owned dogs in New York City deposit about 150,000 pounds of feces and 90,000 gallons of urine each day on streets, sidewalks and park areas.* Even a small number of farm animals can have a significant impact because one cow will generate as much manure as 16.4 humans, a pig will produce as much as 1.9 humans, and 12 chickens as much as one human (Geldreich, 1976). Pollution from wild animals must also be considered. A beach in Madison, Wisconsin was closed to swimming because of high bacterial counts in 1978. An investigation revealed that fecal coliforms deposited by wild ducks had multiplied in the beach sands and were then carried into the water by storm runoff (Standridge and others, 1979).

Variation in Number of Microorganisms in Stormwater

The microbiological character of runoff from any given storm and any given area is likely to be unique. This presents obvious problems if one is to compare runoff between areas or within the same area over time. First, the land use and topography of the drainage area will have a significant effect on quality of the runoff. For example, urban stormwater and runoff from a feedlot will be very different from each other. Even within the general category of urban runoff, water from residential areas is likely to differ considerably from water from commercial areas in terms of microorganisms.

If runoff from only one area is considered, time is the most significant variable because bacterial counts vary from storm to storm (Davis and others, 1977) and with season (see Table 1). However, the amount of time elapsed between storms does not seem to affect microbiological quality, as indicated by Olivieri and others (1977, p. 88), who, after studying storms in Baltimore, Maryland, for a 12-month period, concluded that *the levels of fecal coliforms observed in the storm runoff appear to be independent of the time between storms.* Upon first consideration, this conclusion may seem unlikely because waste material will tend to accumulate between storms. However, fecal organisms begin to die as soon as they leave their normal habitat, the gastrointestinal tract of warm-blooded animals, so that only freshly deposited fecal bacteria are likely to affect the counts in runoff.

Changes in bacterial counts during a storm have been documented by Davis and others (1977), who studied an area near Houston, Texas, that was being developed into a planned community. Figure 1, which shows a hydrograph and bacteriological data from one storm at a small stream site, indicates that the densities of both fecal coliforms and fecal streptococci rise sharply at the beginning of the storm and gradually decay over the next 60 hours. The time from 20-50 hours represents the bulk of the hydrograph. During this period the fecal coliform density decreases by slightly less than 1 log unit (base 10), while the fecal streptococcal density decreases by just over 1 log unit. Qureshi and Dutka (1979a) conducted a similar study of stormwater draining a residential area in Burlington, Ontario, and emptying into a small creek. In that study, samples of runoff were collected at the outfall before entering the stream. Changes in bacterial counts at this site (arithmetic mean of 12 storms) are shown in figure 2. Data for individual storms show no predictable pattern for maximum bacterial populations (Dutka, 1977; Qureshi and Dutka 1979b). In a report on the microbiological quality of stormwater from residential and commercial areas (3 sites), Qureshi and Dutka (1979b, p. 977) concluded:

> *There appeared to be little relationship between the duration, intensity, and amount of rainfall and the occurrence of peak microbial populations. As a result, no typical pattern of time-related distribution of indicator and pathogenic bacteria could be established in this investigation.*

The amount of time microorganisms spend in the stormwater before collection and analysis has a significant effect on the final counts obtained. In

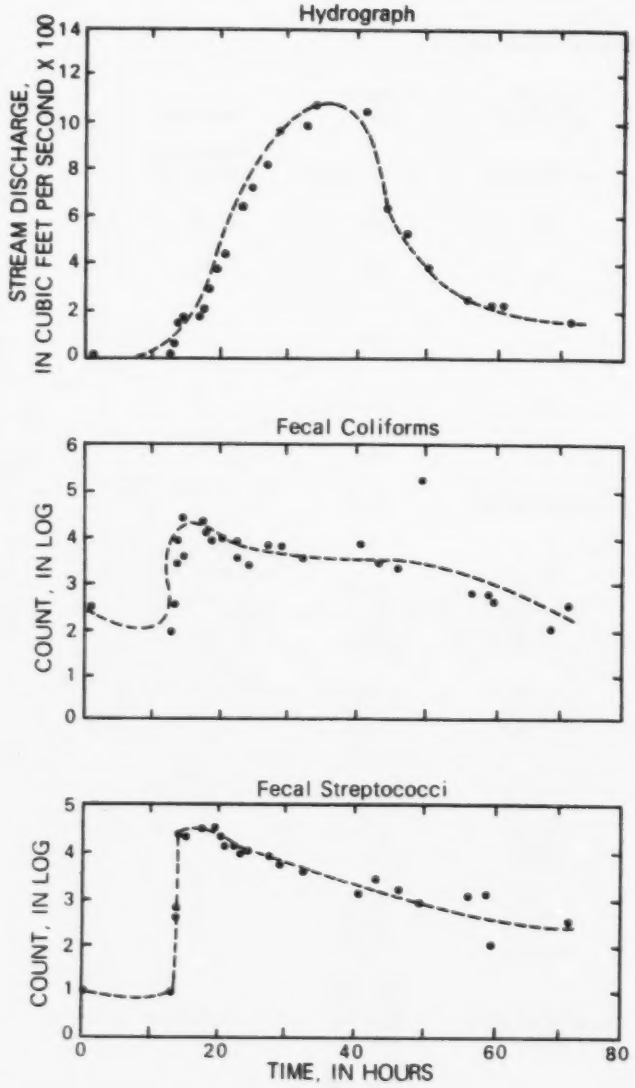


Figure 1 *Hydrograph and densities of fecal coliform and fecal streptococcal bacteria in a small stream near Houston, Texas, during a storm. (Modified from Davis and others, 1977; reproduced with permission of Water Resources Bulletin).*

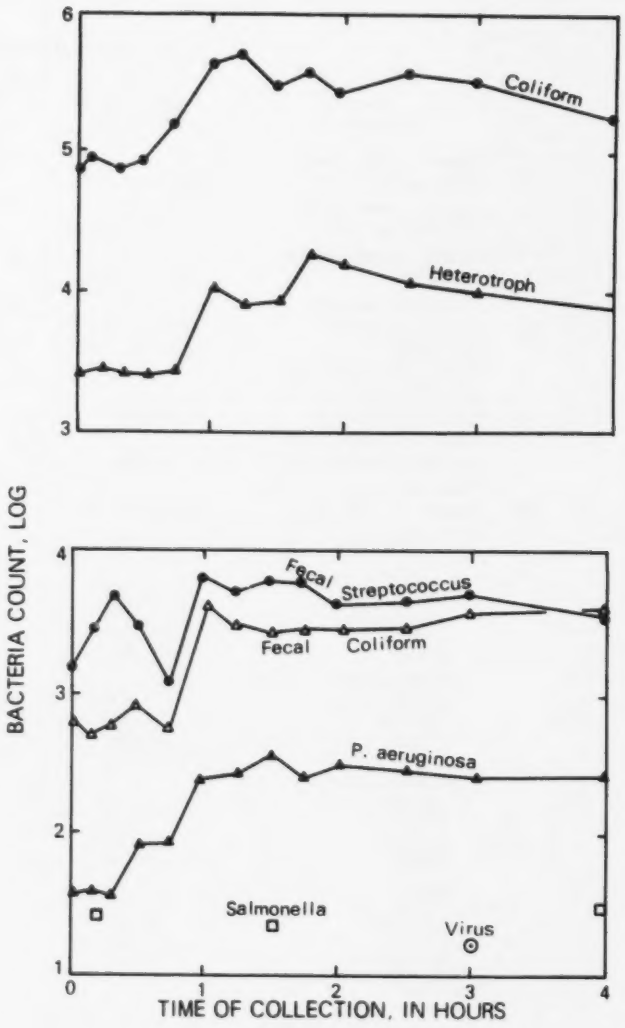


Figure 2 *Bacterial populations in runoff samples taken at stormwater outfall, Burlington, Ontario. Arithmetic mean of bacteriological data based on 12 storms. (From Qureshi and Dutka, 1979; reproduced from Water and Sewage Works, v. 123, no. 3, March 1979, with permission).*

Table 1

DENSITIES OF INDICATOR BACTERIA IN STORMWATER

Source of stormwater	Total coliforms per 100 mL	Fecal coliforms per 100 mL	Fecal strep per 100 mL	FC:FS Ratio	Reference
Detroit - urban street catch basins, 1949	25,000 - 930,000	not measured	not measured	not measured	Weibel and others, 1964
Detroit - urban street catch basins, 1950	2,300 - 430,000	do.	do.	do.	do.
Seattle - street gutters 1959-1960	up to 16,100	do.	do.	do.	do.
Stockholm, Sweden - streets and parks, 1945-1948	median: 4,000 high: 200,000	do.	do.	do.	do.
Pretoria, South Africa - residential, park, school, sports ground areas	240,000	do.	do.	do.	do.
Pretoria, South Africa - business and flat areas	230,000	do.	do.	do.	do.
Cincinnati, Ohio - residential; 1962-1963	median 58,000	median 10,900	median 20,500	0.53	do.
Cincinnati, Ohio - 1962-1964					Geldreich and others, 1968
Wooded hillside					
Spring	2,400	190	940	0.20	
Summer	79,000	1,900	27,000	0.70	
Autumn	180,000	430	13,000	0.03	
Winter	260	20	950	0.20	
Street gutters					
Spring	1,400	230	3,100	0.07	
Summer	90,000	6,400	150,000	0.04	do.
Autumn	290,000	47,000	140,000	0.34	
Winter	1,600	50	2,200	0.02	
Business district					do.
Spring	22,000	2,500	13,000	0.19	
Summer	172,000	13,000	51,000	0.26	
Autumn	190,000	40,000	56,000	0.71	
Winter	46,000	4,300	28,000	0.15	
Rural					do.
Spring	4,400	55	3,600	0.02	
Summer	29,000	2,700	58,000	0.05	
Autumn	18,000	210	2,100	0.10	
Winter	58,000	9,000	790,000	0.01	
Baltimore Inner city, residential commercial-Pop. density 92.5/acre, 1974-1975	mean of 24 storms 380,000	mean of 24 storms 83,000	mean of 24 storms 560,000	90% less than 4.0; 80% less than 1.0	Olivieri and others, 1977.
Baltimore - Residential/shopping center-Pop. density 26.6/acre, 1974-1975	mean of 21 storms 38,000	mean of 21 storms 6,900	mean of 21 storms 50,000	90% less than 4.0; 80% less than 1.0	do.
Burlington, Ontario - single-family residential	10,000	4,000	4,000	1.0	Qureshi and Dutka, 1979a

general, storm runoff is a hostile environment for fecal indicator organisms and pathogens because these organisms require high nutrient levels and warm temperatures for growth. Furthermore, salts, organic constitutents, and other chemicals that may be in stormwater will have an adverse effect on microorganisms, so that the number of organisms in stormwater will decline with time. In addition, the relative concentrations will change with time because the strains die off at differing rates. A more complete discussion of the importance of prompt analysis is presented in the section *Methods and Procedures* (p. 9).

Pathogens in Stormwater

Olivieri and others (1977) investigated the occurrence of pathogens in urban stormwater in Baltimore. An analysis of stormwater samples from a site not known to have any sewage overflows gave the results presented in Table 2.

Table 2
DENSITIES OF PATHOGENS IN STORMWATER FROM BALTIMORE, MARYLAND.[1/]

Pathogen	Percent occurrence in collected samples	Geometric mean densities
Salmonella species	52	5.7 per 10 L
Pseudomonas aeruginosa	100	592 per 100 mL
Staphylococcus aureus	82	12 per 100 mL
Animal virus	83	—
Polio virus	42	—
Coxsackie Virus B	50	—
Echovirus	33	—
other unidentified virus	8	—
Enterovirus	—	170 plaque - forming units per 10 L

[1/]Data from Olivieri and others (1977)

It is obvious that urban stormwater can contain pathogens, although at relatively low levels. Could this represent a threat to human health? One way to begin to answer this question is to consider the number of bacteria and viruses necessary to establish infection. Unfortunately, this number is dependent on the strain of the pathogen involved because some strains are more virulent than others. The susceptibility of a human population is also variable and depends on such considerations as age, general health, and degree of immunity. Nevertheless, rough estimates can be made from available data. A dose of 10^8 *Salmonella* may be necessary to establish infection, but in the case of some *Shigella* strains, 10^2 or 10^3 viable organisms is enough to infect (National Research Council, 1977). The situation with viruses is not as well documented, but in general, from a conservative approach, one virus particle is considered sufficient to establish infection. It should be pointed out, however, that infection does not always lead to disease.

By combining the available information about densities of pathogens in stormwater with the infective doses just cited, one might be able to make an estimate of the direct health hazard of urban runoff. From this line of reasoning, the amount of stormwater an individual would have to consume to acquire a *Salmonella* infection would be on the order of hundreds of gallons. The danger from virus infection may be greater because dilution will not destroy infectivity. It is unlikely that any single individual will consume enough stormwater to insure virus infection, but if many individuals drink slightly contaminated water, it is possible that one or a few may become infected.

Stormwater does not need to be ingested to pose a health hazard. It is perhaps ironic that contamination of salt water, which is not consumed, may be more dangerous than contamination of drinking water. For example, oysters and clams are known to concentrate viruses, and several well-documented outbreaks of hepatitis have been caused by virus-contaminated shellfish (Vaughn and Landry, 1977). Also, *Pseudomonas aeruginosa* and *Staphylococcus aureus* are associated with eye, ear, and skin disease and might become a problem in areas where stormwater, or surface waters heavily contaminated with stormwater, are used for recreational activities.

All of the pathogens mentioned above are of human origin and, as expected, are present in urban stormwater in relatively low numbers. The report on the Baltimore study discusses the issue at some length and concludes that urban stormwater probably represents little threat to public health (Olivieri and others, 1977). However, Van Donsel and others (1967, p. 1362) cite a U.S. Public Health Service analysis of waterborne-disease outbreaks occurring in the United States and Puerto Rico from 1946 to 1960: *At least 29 outbreaks involving 9,233 cases were associated with storm-water runoff, caused either by rainfall washing human and animal feces or sewage into wells, springs, streams, reservoirs, and open water mains, or by wide-spread flooding of individual and public water systems.*

Fate of Microorganisms in Stormwater

As long as stormwater containing bacteria and viruses is confined to gutters, ditches, and storm sewers, it poses little threat to humans; but when it enters the receiving body, the viruses and bacteria may become a problem. Fortunately, bacteria that are adapted to live in or on a human host (pathogens and fecal indicators) are not well adapted for competition and survival in the aquatic ecosystem. McFeters and others (1974) placed enteric bacteria in well water (temperature 9.5 °C to 12.5 °C) inside membrane dialysis chambers. The average time required for a 50-percent reduction in the initial population (half-time) was 17 hours for fecal coliforms and 22 hours for enterococci. Among a

group of pathogens studied, the longest half-time was 26.8 hours (*Shigella* sp.) and the shortest, 2.4 hours (*Salmonella* sp.). The authors observed no growth of the bacteria studied.

Although viruses will not grow outside of their hosts, they apparently do not disappear as rapidly as bacteria. Studies cited by Vaughn and others (1979) indicate that human viruses may persist in aquatic environments for long periods of time, as much as 154 days in one example.

Van Donsel and others (1967) studied the survival of indicator bacteria in soil using tracer strains that could be identified. They found that in summer the fecal coliforms survived slightly longer than the fecal streptococci (3.3 vs. 2.7 days for 90 percent reduction), whereas in spring and winter, the fecal streptococci survived much longer than the fecal coliforms. In autumn, survival time was the same for both types, and the shortest survival time for both groups was at an exposed site in summer. There was some evidence of aftergrowth of nonfecal coliforms. Van Donsel and others (1967, p. 1362) pointed out that this aftergrowth might *contribute to variations in the bacterial count of storm runoff which have no relation to the sanitary history of the drainage area*. The problem of aftergrowth of fecal coliforms deposited by ducks on a beach in Wisconsin (Standridge and others, 1979) has already been described.

Generally, soil is effective in removing bacteria and viruses. Gerba and others (1975) have recently presented an extensive review of this topic. Factors that affect the survival of bacteria in soil are moisture content and moisture-holding capacity, temperature, pH, sunlight, availability of organic matter, and competition and antagonism from soil microflora. Movement of bacteria into the ground water is limited by the straining of bacteria at the soil surface and by adsorption to clays in the soil. Deterioration of ground-water quality from the downward movement of microorganisms is likely to be a problem only where the water table is near land surface.

A recent study (Yeager and O'Brien, 1979) concluded that drying is the most important factor in the inactivation of viruses in soils. Virus removal by soils depends mainly on adsorption by clays (Gerba and others, 1975). However, viruses that are adsorbed to clays can retain their infectivity (Schaub and Sagik, 1975). Binding of virus particles to clay depends on the net charge of the virus, which is in turn dependent on pH. Unfortunately the viruses are not bound irreversibly to the soil particles and may be desorbed by rainwater (Landry and others, 1979). Wellings and others (1975) have isolated viruses from ground water under a recharge basin after a period of heavy rain.

The movement of pathogens to ground water may be a problem in any area where storm runoff is stored in basins or used for artificial recharge. The largest source of information on this hazard is the literature on artificial recharge of ground water and land treatment of sewage. Both practices present a greater potential contamination problem than storm runoff since pathogens will likely be applied to the same land area in greater numbers over a long period of time. Several studies indicate that ground-water contamination from artificial recharge is possible. For example, Vaughn and others (1978) found viruses and bacteria in ground water beneath recharge basins at two Long Island, N.Y., sewage-treatment plants where the depth to water was 18 and 30 feet, but found no viruses under basins that were 80 feet above the water table. However, even where viruses and bacteria were found in the ground water, the numbers had been considerably reduced during passage through the soil. Although the numbers of bacteria and viruses are likely to be much lower in urban stormwater than in treated wastewater, Vaughn and Landry (1977) recovered viruses from ground water beneath a stormwater-recharge basin on Long Island. The source of these viruses has not been definitely established; however, their presence suggests the possibility of ground-water contamination by stormwater.

METHODS AND PROCEDURES

A detailed discussion of the methods used to grow and enumerate microorganisms in stormwater is beyond the scope of this paper. Other sources (American Public Health Association, 1975; Greeson and others, 1977) give much information on the procedures used to cultivate indicator bacteria (fecal coliforms and fecal streptococci). Pathogenic organisms are more difficult to work with, and great care must be exercised to avoid laboratory-acquired infections. Viruses must be grown inside a living host cell, and virus concentration and propagation are complicated processes that should be left to specialists in virology.

Setting aside any discussion of the methods used in processing a water sample, an important issue remains. If the sampling program is improperly designed or if the water sample is collected improperly, the data will be at best meaningless or at worst misleading. Some of the points that must be considered in sampling are addressed in the following statements.

Sample Collection

Stormwater

Water samples for microbiological analysis should be collected by hand in sterile containers by a trained individual (American Public Health Association, 1975). Two early reports (Burm and Vaughan, 1966; Weibel and others, 1964) mention allegedly sterile automatic-sampling devices for stormwater; however, the descriptions of the devices are somewhat incomplete and leave doubt as to the integrity of the sample. Almost all recent papers indicate that stormwater samples were collected by hand in sterile containers. This is obviously expensive and time consuming. It might be argued that since stormwater is already heavily contaminated, slight additional contamination from the sampling device wil be negligible. However, this is circular reasoning, and the true level of contamination in the stormwater can never be established by this approach. Another argument might be that fecal coliforms and fecal streptococci are unlikely to be in the air or in washed bottles and automatic samplers. This argument may seem reasonable; nevertheless, microbiological data reported for samples collected under nonsterile conditions will always be suspect.

Receiving Waters

Collecting stormwater at the outfall of a storm drain will give the best estimate of the microbiological quality of the runoff. However, to judge the impact of stormwater on some environments, it may be necessary to sample a stream or other receiving water. In lakes, reservoirs, deep rivers, and estuaries, bacterial abundance may vary transversely, with depth, and with time of day. The time of day variable was pointed out by Davis and others (1977) in their study of a stream receiving storm runoff. In their study, bacterial densities were not constant in stream waters over a period of 24 hours, even during constant low-flow conditions. Their data showed highly variable batch flows, and they concluded that grab samples reflected the condition and content solely at the time at which the sample was taken. A possible solution to this problem might be to collect samples upstream from the discharge point to serve as a control for each stormwater sample taken.

Storage of Stormwater Samples

The rule when working with microorganisms is that the more rapidly the samples are processed, the more accurate the results will be. Bacterial samples must be refrigerated if held more than 1 hour before processing; the maximum transport time is 6 hours, and the samples must be processed within 2 hours after arrival at the lab (American Public Health Association, 1975; Greeson and others, 1977).

A measure of the potential for survival of various bacterial groups in stormwater is presented in Figure 3, taken from Geldreich (1976). In that study, urban stormwater was collected and filtered to remove the *native* bacterial populations, and pure cultures were added to the water. The culture densities were then determined over a period of 2 weeks. Problems with this approach are that the laboratory cultures might have declined at a different rate than those occurring naturally in stormwater, and also that the added bacteria might have survived longer because they did not have to compete with the *native* population.

As Figure 3 indicates, the apparent number of bacteria decreased significantly with storage time, and different types of bacteria died off at different rates. In general, the bacteria survived longer when stored at 10 °C (fig. 3A) than at 20 °C (fig. 3B), but even when stored at 10 °C (fig. 3A), 50 percent of the *Salmonella typhimurium* died within 2 days. Fecal coliforms survived slightly longer, with 50 percent surviving for 3 days. The rate of decline of fecal streptococci depended on the species under consideration. *Streptococcus*

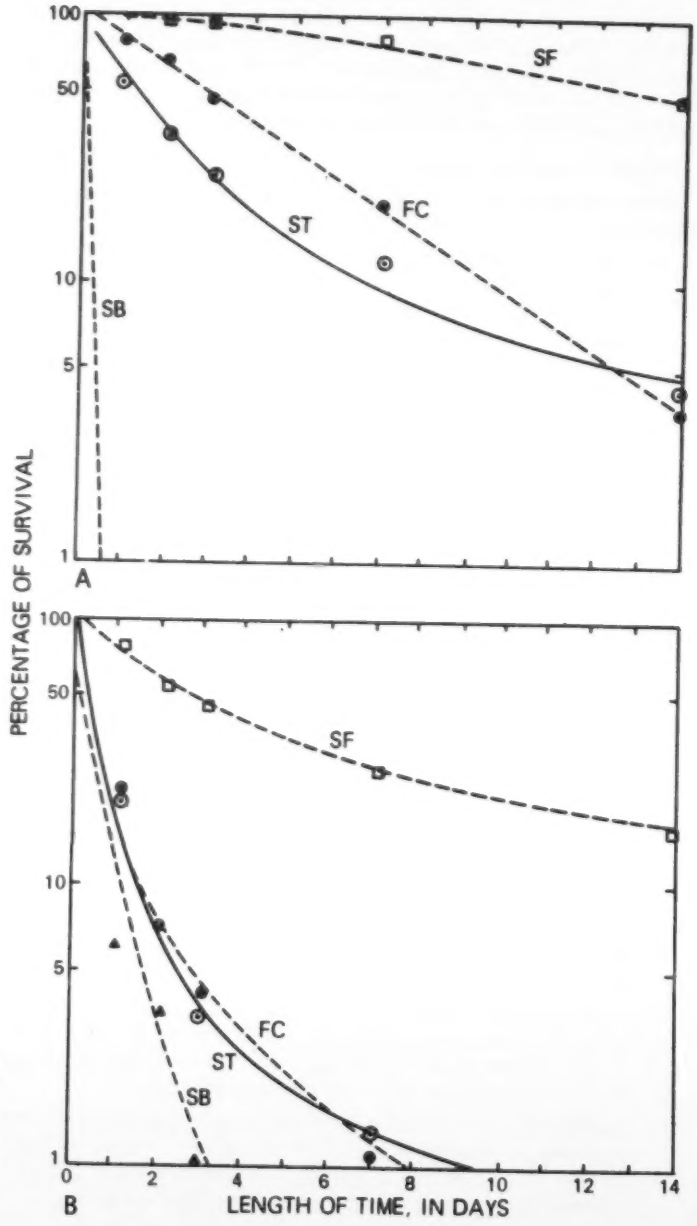


Figure 3 *Persistence of selected bacterial strains in stormwater: A, stored at 10°C; B, stored at 20°C. SF* = Streptococcus faecalis, *FC = fecal coliform bacteria, ST* = Salmonella typhimurium, *SB* = Streptococcus bovis. *(Modified from Geldreich, 1976; reprinted with permission from Critical Reviews in Environmental Control; copyright by The Chemical Rubber Co., CRC Press, Inc.).*

faecalis died off relatively slowly, with 50 percent surviving for 14 days, whereas *Streptococcus bovis* (a component of animal feces but not human feces) disappeared within the first day at 10°C and within 3 days at 20°C. These data clearly support the general rule that rapid processing of microbiological samples is of utmost importance.

Design of Sampling Program

When designing a program to determine the microbiological quality of stormwater, one must consider the following points:

1. The number and type of bacteria in runoff will be influenced by the intensity of the storm, duration of the storm, season of the year, and land use of the area being drained. Therefore, great care must be taken in any extrapolation from one area to another or from one storm to another.
2. Provision must be made for a nearby laboratory to handle all samples. Samples must be processed within hours of collection.
3. No good predictor or indicator for the presence of pathogens in stormwater is known. Pathogenic bacteria and viruses seem to occur in a random fashion throughout the storm.

SUMMARY AND CONCLUSIONS

Information obtained from recent investigations of microorganisms in stormwater has been reviewed and summarized with the intent of providing assistance to those planning studies of stormwater. The following conclusions are indicated by this review:

1. Most stormwater contains relatively large numbers of total coliforms, fecal coliforms, and fecal streptococci.
2. Most of the total coliforms in runoff are native soil organisms.
3. The source of most fecal coliforms and fecal streptococci in runoff is probably wild or domestic animals.
4. A report from Baltimore, Maryland has documented the occurrence of hazardous organisms in urban runoff. The source of this contamination is unknown.
5. Stormwater probably presents little direct threat to human health because it is not ingested, but it can produce other negative effects such as contamination of beaches or shellfish.
6. Contamination of surface water by bacteria in stormwater is of short duration because indicators and pathogens die out rapidly in the aquatic environment. Viruses apparently do not disappear as rapidly as bacteria and may be concentrated by shellfish.
7. Bacteria and viruses deposited on soil by stormwater are inactivated by drying, competition from soil microflora, and a variety of other processes. The movement of pathogens to ground water is likely to be a problem only where the water table is near land surface.

REFERENCES CITED

American Public Health Association, 1975, *Standard methods for the examination of water and wastewater,* (14th ed.): Washington D.C., American Public Health Association, 1193 p.

Burm, R.J., and Vaughan, R.D., 1966, Bacteriological comparison between combined and separate sewer discharges in southeastern Michigan: *Journal Water Pollution Control Federation,* v. 38, p. 400-409.

Carberry, J.B., and Stapleford, L.R., 1979, A consideration of microbial water quality analysis criteria: *Journal American Water Works Association,* v. 71, p. 213-218.

Davis, E.M., Casserly, D.M., and Moore, J.D., 1977, Bacterial relationships in stormwaters: *Water Resources Bulletin,* v. 13, p. 895-905.

Dutka, B.J., 1973, Coliforms are an inadequate index of water quality: *Journal of Environmental Health,* v. 36, p. 39-46.

———, 1977, Microbiological study of storm runoff waters from a 100% residential area in Canada: *Canadian Research,* v. 10, p. 32, 51-53.

Geldreich, E.E., 1976, Fecal coliform and fecal streptococcus relationships in waste discharges and receiving waters: *Critical Reviews in Environmental Control,* v. 6, p. 349-369.

Geldreich, E.E., Best, L.C., Kenner, B.A., and Van Donsel, D.J., 1968, The bacteriological aspects of stormwater pollution: *Journal Water Pollution Control Federation,* v. 40, p. 1861-1872.

Geldreich, E.E., and Kenner, B.A., 1969, Concepts of fecal streptococci in stream pollution: *Journal Water Pollution Control Federation,* v. 41, p. R336-R352.

Gerba, C.P., Wallis, C., and Melnick, J.L., 1975, Fate of wastewater bacteria and viruses in soil: *Journal of the Irrigation and Drainage Division, American Society of Civil Engineers,* v. 101, p. 157-174.

Greeson, P.E., Ehlke, T.A., Irwin, G.A., Lium, B.W., and Slack, K.V., editors, 1977, Methods for collection and analysis of aquatic biological and microbiological samples: *U.S. Geological Survey Techniques of Water-Resources Investigations,* Book 5, Chapter A4, 332 p.

Landry, E.F., Vaughn, J.M., Thomas, M.Z., and Beckwith, C.A., 1979, Adsorption of enteroviruses to soil cores and their subsequent elution by artificial rainwater: *Applied and Environmental Microbiology,* v. 38, p. 680-687.

Marzouk, Y., Goyal, S.M., and Gerba, C.P., 1979, Prevalence of enteroviruses in ground water of Israel: *Ground Water,* v. 17, p. 487-491.

McFeters, G.A., Bissonnette, G.K., Jezeski, J.J., Thomson, C.A., and Stuart, D.G., 1974, Comparative survival of indicator bacteria and enteric pathogens in well water: *Applied Microbiology,* v. 27, p. 823-829.

National Research Council, Safe Drinking Water Committee, 1977, *Drinking water and health:* Washington, D.C., National Academy of Sciences, 939 p.

Olivieri, V.P., Kruse, C.W., Kawata, K., and Smith, J.E., 1977, *Microorganisms in urban stormwater, Cincinnati, Ohio:* U.S. Environmental Protection Agency, EPA-600/2-77-087, 181 p.

Qureshi, A.A., and Dutka, B.J., 1979a, Storm runoff microbiology adds to concerns: *Water and Sewage Works*, v. 123, p. 86-88.

———, 1979b, Microbiological studies on the quality of urban stormwater runoff in southern Ontario, Canada: *Water Research*, v. 13, p. 977-985.

Schaub, S.A., and Sagik, B.P., 1975, Association of enteroviruses with natural and artificially introduced colloidal solids in water and infectivity of solids-associated virus: *Applied and Environmental Microbiology*, v. 30, p. 212-222.

Standridge, J.H., Delfino, J.J., Kleppe, L.B., and Butler, R., 1979, Effect of waterfowl *(Anas platyrhynchos)* on indicator bacteria populations in a recreational lake in Madison, Wisconsin: *Applied and Environmental Microbiology*, v. 38, p. 547-550.

Van Donsel, D.J., Geldreich, E.E., and Clarke, N.A., 1967, Seasonal variation in survival of indicator bacteria in soil and their contribution to storm-water pollution: *Applied Microbiology*, v. 15, p. 1362-1370.

Vaughn, J.M., and Landry, E.F., 1977, *An assessment of the occurrence of human viruses in Long Island aquatic systems:* Upton, New York, Brookhaven National Laboratory Associated Universities, Data Report BNL 50787, 130 p.

Vaughn, J.M., Landry, E.F., Baranosky, L.J., Beckwith, C.A., Dahl, M.C., and Delihas, N.C., 1978, Survey of human virus occurrence in wastewater-recharged groundwater on Long Island: *Applied and Environmental Microbiology*, v. 36, p. 47-51.

Vaughn, J.M., Landry, E.F., Thomas, M.Z., Vicale, T.J., and Penello, W.F., 1979, Survey of human enterovirus occurrence in fresh and marine surface waters on Long Island: *Applied and Environmental Microbiology*, v. 38, p. 290-296.

Weibel, S.R., Anderson, R.J., and Woodward, R.L., 1964, Urban land runoff as a factor in stream pollution: *Journal of Water Pollution Control Federation*, v. 36, p. 914-924.

Wellings, F.M., Lewis, A.L., Mountain, C.W., and Pierce, L.V., 1975, Demonstration of virus in groundwater after effluent discharge onto soil: *Applied and Environmental Microbiology*, v. 29, p. 751-757.

Yeager, J.G., and O'Brien, R.T., 1979, Enterovirus inactivation in soil: *Applied and Environmental Microbiology*, v. 38, p. 694-701.

Appendix D

Control Measure Evaluation
Lawler, Matusky and Skelly Engineers
and Fanning and Phillips
Final Draft Report to the Long Island Regional
Planning Board, June 1982, Chapter 5

Preceding page blank

CHAPTER 5.0

CONTROL MEASURES

5.1 CONTROL MEASURE SCREENING

Runoff to south shore shellfish waters is

- discharged from the many freshwater streams tributary to the shoreline bays and inlets
- discharged directly into shoreline bays and inlets from direct overland flow from the shoreline strip area, and from the storm sewer system serving this shoreline or overland area.

Accordingly, control measures to reduce the coliform bacterial load in the runoff have been categorized according to which of these two areas they might serve, i.e, stream runoff or overland area runoff. Many control measures were screened prior to analysis of those thought to be applicable to the study area. That screening is as follows:

Stream Runoff Control Measures

- Wetlands
- Pond Modification - Dredging
  Baffling with full and partial gabion walls
  Creating swirl concentrators out of ponds
  Center inflow/peripheral outflow
  Sheet piling
  Rock piles
  Inlet and outlet weirs
- Dry Streambed Infiltration

Overland Area Runoff Control Measures

- Leaching catch basins
- Street sweeping
- Animal ordinances
- Use of existing storm drainage system
- Wetlands

Stream Runoff

Wetlands - An EPA-supported experiment in Wisconsin on the use of wetlands to remove coliforms was reviewed for its applicability to Long Island. It was concluded that it was applicable and that land requirements would be too large for the runoff loads to be encountered. Wetlands were therefore not considered to be feasible to the solution of the Long Island runoff problem.

Since wetlands do exist on Long Island, consideration might be given to some experimentation regarding their use since site-specific differences could exist between Long Island and the experimental site evaluated. However, it should be noted that vegetation types at the experimental site were very similar to Long Island vegetation. Further discussion of the applicability of the experimental site results to Long Island is presented later in this chapter.

Dredging - Dredging to enlarge existing pond volumes and to create new ponds appears feasible. It is a proven technology. Costs are reasonable. Ecological impacts are mostly temporary. There is experience with this on Long Island, since some existing ponds have recently undergone dredging in order to maintain or improve them. It is also possible that some urban runoff dredging projects could be viewed as serving the objectives of another program and funded thereby.

Baffling - Baffling with gabion walls across pond inlets and outlets was considered as a way of dissipating streamflow energy and thereby eliminating most of the short circuiting believed to be exhibited by ponds. The technology is simple and inexpensive. Gabions are not permanent structures and can be installed and removed without great difficulty. Void spaces should be sufficient to avoid any serious hydraulic problems. A solid wall of gabions, however, will cause accumulation of sediment and debris which will require periodic maintenance of the gabions. Fish passage from ponds to upstream areas will be interfered with unless some openings in the gabion walls are left. Fish passage up Long Island streams does not appear to be significant, however, gabion installation is flexible enough to allow the option of leaving open spaces in gabion walls to allow for such passage. The use of gabions is judged to be an effective way of reducing pond short circuiting. Performance criteria should be established through in situ testing.

Problems may arise with maintenance of the gabions. Accordingly an alternative gabion arrangement, in which passageways are left between gabions, should be field tested. This will reduce the energy dissipation effect of the gabions but the improvement in maintenance characteristics may be worth the trade-off. Further discussion of gabions as a baffling technique is provided later in this chapter.

Swirl Concentrator - If the inflow to a pond were directed by means of a baffle to the periphery of the pond as it entered, circular motion might occur. This motion could result in concentric travel paths being taken by the flow as it traveled through the full volume of the pond toward discharge, through an outlet device that would be constructed in the center of the pond. Such an arrangement would improve the detention time and settling characteristics of the pond.

Inspection of Long Island ponds reveals that they generally are not circular so circular motion would be hard to induce. Also it is very doubtful that there would be enough velocity to maintain such motion, giving rise to substantial short circuiting. The flow would head right for the center. It was concluded that the problem with this technique was one of scale. The ponds are too large. This technique is not feasible.

Center Inflow - The effectiveness of circular clarifiers in sewage treatment plants prompted consideration of their characteristics as potentially applicable to ponds. A small center inflow is discharged radially in all directions and outflow is picked up on the periphery. It was thought that such an arrangement applied to ponds would improve the utilization of pond volumes and make them more effective. The problem with the approach is that the ponds are not circular and flow discharged at the center would therefore tend to take the shortest path to a peripheral outlet, introducing considerable short circuiting. Control over outlet ports to try to minimize this effect would require frequent checking and fine tuning. In addition, this control measure would be costly due to construction and operation. It was regarded as not feasible.

Sheet Piling - Sheet piling was considered as a possibility for baffling at the inlet and outlet points of ponds. It could act as a weir if put in as a solid wall or as a baffle if sections of the wall were left open. The technology is proven and the material is rugged. Ecological impacts should be minimal as they would be with gabions. A solid wall would cause an accumulation of sediment and debris on the upstream face. Sheet piling was thought to be feasible but nevertheless was eliminated from further consideration because installation costs would be high and the structure, being somewhat permanent, would not be amenable to removal or rearrangement. The piling would be difficult to adjust if problems arose.

Rock Piles - This technique would be similar to the use of gabions however, wire cages would not be used to hold the rocks. Rock piles could be placed in either a solid wall or as individual piles with passageways in between. Ecological impacts would be small. The material is obviously natural in appearance. Installation costs would be low and the piles could be moved or adjusted as needed. This is a reasonable alternative to gabions. It would probably be more expensive though since it would require more rocks than the gabions would in order to provide stability.

Inlet and Outlet Weirs - Weirs could be used to create a more uniform distribution of flow lines than occur naturally at pond inlets and outlets. They would require a foundation and therefore be expensive to install. They have a very small tolerance for changes in level and so are more amenable to use in protected or controlled situations. Weirs are regarded as feasible in special situations but not as a generally applicable control measure.

Dry Streambed Infiltration - Dry streambeds are predicted to occur as a result of sewer installation in Nassau and Suffolk counties. Sewage normally discharged to the groundwater table will be diverted by sewers. As a result, the groundwater table will drop below the bottom of many streambeds causing them to dry up. This presents an opportunity then for these beds to infiltrate the runoff that is directed to them by the storm sewer system. The extent of drying has been identified by the Flow Augmentation Needs Studies conducted by Nassau and Suffolk. The methodology for calculating the degree of infiltration is presented later in this chapter.

Overland Area Runoff

Leaching Catch Basins - Since the application of structural control measures in the overland shoreline area is extremely difficult, considerable thought was given to this technique for controlling runoff. Discussion of leaching catch basins is provided later in this chapter as well as in Appendix D. The final conclusion was that the depth to groundwater and the hydraulic conductivity limitations of peninsula soils preclude consideration of this technique as generally applicable in the overland or shoreline strip.

Street Sweeping - References in the literature are very limited regarding the removal of coliform bacteria through street sweeping. Accordingly, definitive statements as to its effectiveness must await the in situ testing of this control measure by the Suffolk County Department of Health Services. A preliminary assumption might be made, however, anticipating that it will be somewhat effective.

Animal Ordinances - Data indicate that animals are the source of the problem of coliform in runoff. Therefore, it is reasonable to consider institutional means for controlling them, particularly in the overland runoff areas where structural control opportunities are minimal. Further discussion of this control measure is presented later in this chapter.

Existing Storm Drainage System -

(a) The overland runoff area is extensively served by a storm sewer system. Street gutters channel runoff into catch basins which discharge to the storm sewers leading to the shoreline bays and inlets.

Consideration was given to using this extensive underground system to infiltrate runoff into the soil instead of discharging it to bays and inlets. The technique would be to drill or otherwise put holes in the sides of existing catch basins so that stormflow would infiltrate out of the basin. A blockage would be put in the way of the exit sewer so that a depth of water would build up, be contained, and infiltrate out of the basin. An overflow would be arranged so that in severe storms, flow would pass into the exit sewer preventing the occurrence of surface flooding at the catch basin. This technique would work well for individual catch basins. However, when such basins are linked to one another via storm sewers, downstream basins back up and affect the upstream basins. There would be hydraulic interference introduced into the existing storm system that would jeopardize its functioning as a drainage and flood control system. In addition, creating holes in the walls of existing catch basins would be extremely expensive since such a procedure is quite time-consuming.

(b) If the runoff entering the existing catch basins could be filtered within the catch basins without interfering with their hydraulic operation, perhaps enough removal could be accomplished in conjunction with street sweeping and animal ordinances to be effective in controlling the overland runoff load. No literature has been found that discusses this concept, but given the difficulty encountered in trying to control the overland area, further investigation and experimentation may be warranted. A filtering device that would be fitted to a catch basin would have to have the following characteristics:

(1) It would have to be fitted high enough in the catch basin so that it would not interfere with the hydraulics of the basin. This would place it at some point above the inlet pipe.

(2) It would have to have an overflow to allow high flows to bypass it and to allow bypassing when clogged.

(3) It would have to be easily maintained. If the filtering media were contained within a rigid, but porous container, the container could be periodically tipped or reversed if it was supported on an axle lodged in the catch basin walls. This would allow the runoff flow to backwash the filter, and the backwash would not be contributing anything to the catch basin that it would not normally receive. Depending upon the filter media, it might even be contained in an element that could snap onto the underside of the storm grate. Then the grate could be lifted periodically to rotate or replace the filter.

(4) It would have to be low in capital cost, since so many would have to be installed.

A number of filter media would have to be tested for coliform removal effectiveness, and to determine loading rates, given both the coliform and suspended solids concentration of runoff. Some of the materials tested might include sand, fabric, or fiberglass.

Some alternate designs would have to be prepared and tested for routing inflow, from both street grates and curb inlets, to the filter media. Alternate overflow mechanisms would also have to be designed and tested.

It is recognized that filtration within a catch basin is highly problematical. The basic operational problem will be frequency of clogging. If the filters do not work for a number of storms, the technique will be impractical. The basic design problems are mechanical design and filter media selection. It is felt that the mechanical problems of suspending the filter so that it will not interfere with catch basin hydraulics, and also be amenable to easy access for maintenance, can be solved. The questions of clogging and filter media selection are much more uncertain. Catch basin filtration is obviously not considered feasible at this time but it is suggested for further consideration given the difficulty of controlling runoff from the overland area.

Wetlands - Freshwater wetland requirements were taken to be indicative of the requirements for salt water wetlands which is to say that the land required for coliform reduction would still be very large. This, coupled with the scarcity of wetlands in the developed peninsula areas, led to the conclusion that wetlands were not a feasible control measure for the overland area.

5.2 PHYSICAL CONTROL MEASURES

Street Sweeping

Street sweeping is a control measure that has been proposed for in situ testing to determine its applicability to solving the urban runoff problems of Long Island. The testing is about to start shortly. As of this writing it is uncertain as to whether such a measure will be helpful in reducing the bacterial load discharged to the south shore shellfishing waters. During the literature search conducted in the early part of the study, only one reference, Pitt (1979), was identified that commented on the suitability of street sweeping for the control of bacteria. Therein it was noted that streetsweeping has a low to medium suitability for such control, but no back-up information was presented for this opinion. It therefore appears that the in situ testing about to begin will provide the only definitive data base upon which to make a judgment. If street sweeping proves successful, its applicability to the shoreline strip along the south shore should be helpful. However, its use as a control measure in an overall plan must be considered tentative pending implementation of the testing.

5.2.1 Storage

5.2.1.1 Bacterial Die-off. Bacterial die-off in storage ponds is accomplished over time generally in accordance with Chick's Law, i.e., % of the load remain-

ing = $e^{-K_e t}$, where k_e is the bacterial die-off rate in units per day and t is the time in days.

The significance of the die-off rate can be seen by converting k_e to the base 10 (k_{10}) and plotting on semi-log graph paper. Figure 5.2-1 is such a plot and demonstrates the sensitivity of removal to the die-off rate operating in the system, which in this study will be a storage pond. Note that there is 90% removal, or a decrease of 1 order of magnitude, in 1 day for a K_{10} of 1.0. If the rate were slightly higher, 1.3, then 95% would be removed in 1 day.

Time is operative in ponds since they allow for the temporary storage of flow. However, short circuiting, which will reduce storage time, is also believed to be operative. In order to demonstrate the presence of short circuiting and its impact on the effectiveness of storage, a dye study was performed on Unqua Pond by the Nassau County Health Department. Dye in the amount of 0.883 lbs, was mixed with the influent to the pond. Rainfall, flow, dye concentration, and coliform concentration were then measured over a 45-hour period, more frequently at the effluent than influent. Analysis of these data provides insight to the extent of short circuiting operating in the pond during the storm measured.

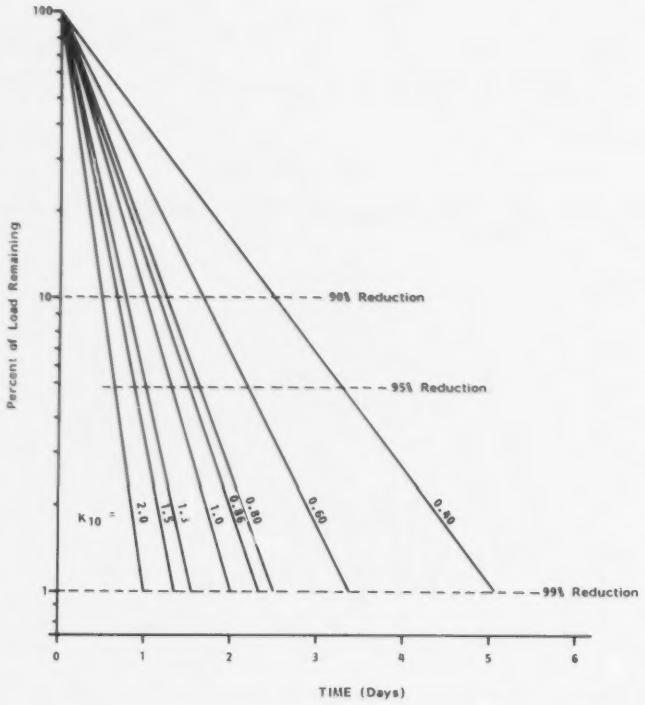


FIGURE 5.2-1 *Coliform reductions (percent reduction vs. time)*

A plot of the effluent dye concentration over time is shown in Figure 5.2-2. As occurs with most dye studies, the distribution is skewed — a sharp front, a peak concentration, then a gradual tailoff. If there were no loss of dye, and the flow was constant, then the point at which the dye concentration peaks would be instrumental in determining short-circuiting. The volume of effluent flow (from the time of discharge to the time of peak) divided by the total pond volume would be the effectiveness of the pond.

The flow, however, is not constant. More importantly, the dye is not conservative; it is disappearing with time. This can be seen by looking at the measured concentrations. The total pond volume is 784,306 ft^3; if the 0.88 lbs of dye were completely mixed in the pond, the mixed concentration would be 18 ppb, and the minimum peak concentration observed under any other condition of mixing should always be higher than this. However, the highest measured peak concentration observed in the effluent was 15 ppb, indicating that dye was being lost.

There are several mechanisms by which the dye could be lost. Adsorption on suspended solids, plants, or pond bottom; photochemical breakdown, or chemical reactions could be occurring. Most of these types of disappearances can be represented by first order reactions. By determining a first order disappearance rate, the observed values can be corrected to non-decayed values, and then used to determine the pond's short-circuiting.

A small computer program was written to iteratively calculate the disappearance rate. This was done by initially assuming a disappearance coefficient, correcting the dye concentrations, integrating the total load and comparing this to the original amount released. Using this procedure, a first order rate of 1.0 per day was determined, which is supported by the literature (QLM, 1969).

Since the flow varies, the procedure used to determine pond short-circuiting was as follows. The cumulative effluent load (flow times corrected concentration times time) was plotted versus time (Figure 5.2-3). The time at which half of the released dye (.88/2 = .44 lbs) had passed was noted. The cumulative effluent volume over this time (also Figure 5.2-3) was calculated and this volume, divided by the pond's total volume, gives its effectiveness or degree of utilization of pond volume by the influent flows. If the transport through the pond was plug flow, then the computed effluent volume would be the pond's volume, as the total pond would have to be displaced for the released dye to reach the discharge.

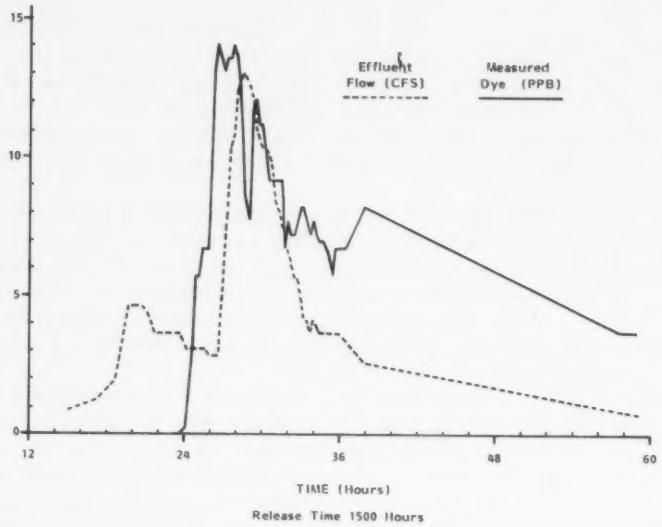


FIGURE 5.2-2 *Dye survey at Unqua Pond (comparison of effluent flow and dye levels)*

The effluent volume at the 1/2 dye load discharge is 470,000 ft³ (Figure 5.2-3). Dividing by the pond volume of 784,306 ft³ gives an effectiveness of 60%, or a short circuiting of 40%. If the disappearance rate were changed, or there was some other loss of dye, the effectiveness of the pond could be drastically different. The 40% given above is the most conservative estimate; for example, if the actual data are used without correcting for the losses, the short circuiting could be as high as 80%.

As a result, the best statement to make about short circuiting in Unqua Pond for this dye study is that the lower and upper bounds are 40 and 80%, respectively, with the actual values being closer to 40%.

During the dye study, coliform sampling also took place and the largest proportion of effluent load to influent load, to date, was tracked. Figure 5.2-4 shows the influent and effluent coliform concentrations over time. Notice the distinct peaks and valleys in each plot; all are spaced by 9-10 hours, which is also the time span from which the dye was released until it first appeared at the discharge. Three methods were used to determine die-off rates using these data: (1) individual influent and effluent peaks and valleys were compared; (2) the influent average peak was compared with the effluent average peak; and (3) the influent numbers over a limited period were compared with the effluent numbers over the same, time-lagged period.

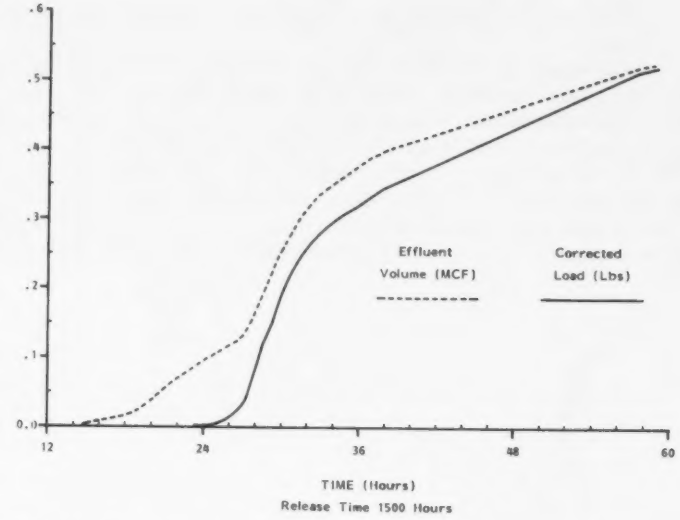


FIGURE 5.2-3 *Dye survey at Unqua Pond (corrected dye load and effluent volume)*

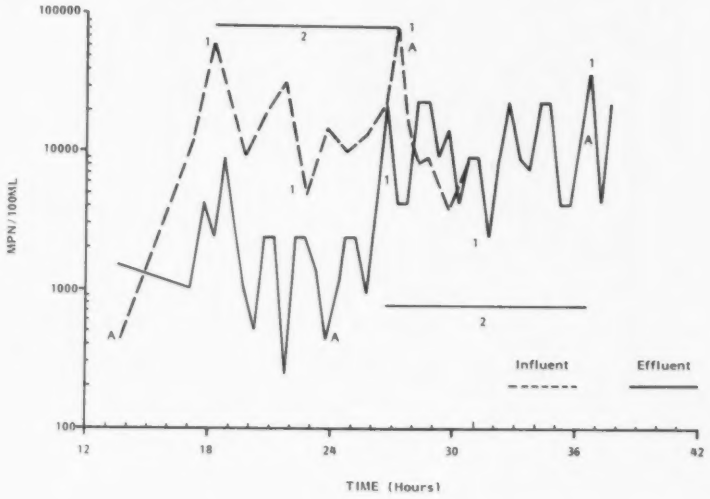


FIGURE 5.2-4 *Dye survey at Unqua Pond (coliform data)*

Individual peaks and valleys are denoted by "1" in Figure 5.2-4. The results of the analysis are:

Method (1)

Influent Concentration (MPN/100 ml)	Effluent Concentration (MPN/100 ml)	Lag Time (Hrs)	Computed Die-off Rate (Base e) (Per Day)
63,238	24,000	8.5	2.74
4,724	2,400	9.0	1.81
83,517	39,000	9.5	1.92

Method (2)

The average influent peak is 55,360 MPN/100 ml and the average effluent peak is 28,220 (over the periods denoted by "2" in Figure 5.2-4). The average lag time is 9 hrs, resulting in a die-off rate of 1.80 per day (Base e).

Method (3)

The total influent number over the period denoted by "A" is 1.84×10^{12} MPN, the total effluent number is 9.86×10^{11} MPN, resulting in a total removal of 46%. Over a 9 hour lag time period, this represents a die-off rate of 1.63 per day (Base e).

Knowing the lag time between influent and effluent during the dye study storm was the key to using the foregoing three methods to calculate bacterial die-off rates. However, dye was not used in the other storm events sampled at Unqua Pond, and a different approach was used to calculate the rates for these storms. The essence of this approach is as follows.

In order to use Chick's Law, the fraction of the bacterial load remaining in the effluent must be known, and the length of time, over which bacterial decay of the load has occurred, must be known. Chick's Law can be written:

$$\frac{L_t}{L_o} = e^{-kt}$$

where

L_t = the bacterial load remaining in the effluent at time t after the storm began

L_o = bacterial load that would have reached the effluent point at time t, had it not decayed during its travel

k = bacterial die-off constant

t = the time of travel for L_o to reach the effluent point had there been no decay

Consider the effluent sampling point to be analogous to a bottle containing a water sample with a given bacterial load L_o, determined by taking an initial sample from the bottle. After time t, a sample is withdrawn and the load remaining due to decay is determined, i.e., L_t. The die-off constant k, remains as the only unknown in Chick's Law and is solved for. However, the effluent sampling point is not a bottle so sampling at the effluent cannot give us an estimate of L_o; only L_t, the amount of the load remaining. But remaining from what? If the total influent load has not passed the effluent point by the time effluent sampling stops, then L_t is remaining only from a portion of the total influent load. (Note that in all storms effluent sampling did cease before the total influent load passed the effluent point). What is needed then is an estimate of that portion (L_o) of the total load which has decayed to become L_t. Note that in the dye study, the pattern of dye concentration followed the pattern of effluent flow rather well (Figures 5.2-2 and 5.2-3). This indicates that tracking effluent volume as a percent of total storm volume is a reasonable way of estimating L_o which decays to become K_t. For example, if after the storm is over, only 30% of the storm volume passed through the pond when effluent sampling ceased, then it is estimated that 30% of the total bacterial load is what also has passed through the pond, and has decayed to L_t. The 30% portion of the total load is what would be referred to as the L_o for the effluent point. The time over which decay of this load has taken place would never be greater than the time between initiation of storm inflow and cessation of effluent sampling. Therefore, this time interval was selected as a conservative estimate of the value t to use in applying Chick's Law to determine the die-off constant, k. If a shorter time were used the die-off constant would be higher. The foregoing approach was used to calculate the die-off constants for the eight storm events of Unqua Pond reported in Chapter 4.0. Its application is shown in Table 5.2.-1.

Further insight as to the magnitude and variability of bacterial die-off rates can be obtained by referring to the literature. Mitchell and Chamberlin (1978) reviewed 28 studies of freshwater die-off rates of coliform bacteria measured in situ. The median die-off rate as K_{10} was 0.41 per day and ranged from 0.18 to 11.35 per day. Twenty percent of the rates are shown to be 1.0 per day.

Some of the values reported were as follows:

Leaf River (Mississippi)	—	0.18
Ohio River	—	0.46 to 0.52
Upper Illinois River	—	0.25 to 1.08
Maturation Ponds	—	0.86
Cumberland River	—	2.37
Shallow Turbulent Stream	—	6.5
Glatt River	—	11.35

Zanoni et. al., (1978) reported an in situ bacterial die-off rate of 3.79 (K_{10}) for Lake Michigan off of Milwaukee harbor. The rate is reported as having been corrected for the dilutional effect of lake waters.

Table 5.2-1

BACTERIAL DIE-OFF ANALYSIS

Storm Date	Rainfall Vol. (inches)	Total Storm Load at Influent ($\times 10^{12}$MPN)	% of Load Passing Through Pond*	Amount of Load Passing Through L_o For Effluent ($\times 10^{12}$MPN)	Total Load Measured at Effluent L_t ($\times 10^{12}$MPN)	Time of Effluent Observation t (days)	Fraction Remaining L_t/L_o	** k_e (per day)	*** k_{10} (per day)
9-18-80	0.54	8.7	29%	2.5	1.0	0.19	0.40	4.8	2.1
9-25-80	0.38	12.7	32%	4.1	0.05	0.24	0.01	19.2	8.4
10-3-80	0.43	1.8	55%	1.0	0.04	0.31	0.04	10.4	4.5
10-25-80	1.30	10.9	90%	9.8	4.6	0.81	0.47	0.9	0.4
11-17-80	0.45	3.3	27%	0.9	0.05	0.58	0.06	4.8	2.1
2-2-81	0.58	2.07	55%	1.14	0.38	0.5	0.33	2.2	1.0
7-1-81	0.25	2.1	7%	0.2	0.6**	0.78	—	—	—
7-20-81	1.17	43.7	65%	28.4	4.3	2.10	0.15	0.9	0.4

* Load passing through pond based on $\frac{\text{Volume of water out when effluent sampling ceased}}{\text{Total volume of storm water that entered pond}}$

** Effluent larger than influent. May be data anomaly or due to some unaccounted for localized effect. Note that very small percent of storm flow passed through pond prior to termination of sampling.

*** $k_e = 2.3\, K_{10}$

Example: Fraction remaining $= \frac{L_t}{L_o} = e^{-k_e t}$

For Storm 9-18-80:

Fraction remaining: $= \frac{1.0}{2.5} = e^{-k_e \times 0.19}$

$$\frac{\ln (1.0/2.5)}{0.19} = -k_e \ln(e)$$

$$\frac{-0.91}{0.19} = -4.81 = -k_e;\ k_e = 4.81;\quad K_{10} = \frac{4.81}{2.3} = 2.09$$

Mancini (1978) reports a freshwater die-off rate of 0.8 per day, to the base e, which when converted to the base 10 is 0.35 per day. In discussions with Mancini, he noted that this rate was based primarily on laboratory data and did not include the effects of solar radiation i.e., visible and near visible light. A rule of thumb, the correction that can be applied to such a rate to account for this effect is to increase its magnitude by one third. This would result in a die-off rate of 0.46. Mancini noted that rates higher than this are not uncommon in nature.

It is, therefore, not unreasonable to expect a die-off rate of 1.0 (base 10) based on in situ data and on the literature. And if the total load can be held for a day then about 90% of it can be removed.

Holding the total load for a day requires that total baseflow and stormflow be stored. Chapter 7.0 presents the values of the daily volumes that must be stored and the bacterial load contained therein which must be reduced, in order to meet shellfish standards. The lower the percentage removal, the

Note that when using storage to remove coliforms, the runoff flow, which is lower the number of shellfish acres capable of meeting standards and being opened. Chapter 6.0 presents a detailed discussion of the potential to open shellfish areas as a function of the percent removal of coliform loads.
a surrogate for bacterial load, must be considered in terms of its volume and not in terms of its flow rate. Flow rate will be important in considering infiltration as a control measure.

Example of Storage Calculation

The use of storage to reduce coliform concentrations is demonstrated in the following evaluation of overall load reduction for Seaford Creek.

The general procedure is to first take credit for any load reduction that will occur through infiltration of the flow through dry streambeds. The

methodology for doing this is presented later in this chapter and the complete streambed analysis for each stream is presented in Chapter 7.0 and Appendix E. The remainder of the load is applied to storage — existing and new — on the stream, and the load reduction is calculated using the bacterial die-off equation, which is:

Fraction of coliform load removed in time t $= 1 - 10^{-k_{10}t}$
where k_{10} is the die-off or removal constant and t is the storage or retention time imposed on the load.

The retention time in days is calculated by dividing the storage provided, by the storage required for one day of retention of the flow remaining after streambed infiltration. Although measures will be taken to eliminate short circuiting in storage ponds, it is presumed that 20% short circuiting will still occur and only 80% of the storage volume will be available for retention. To account for this, the storage required will be calculated as 1.25 times the daily load volume ($1.0 \div 0.8 = 1.25$). All load reductions are then added up and divided by the total load to get the overall load removal effectiveness.

The foregoing procedure as applied to Seaford Creek produces the following:

Total Load:	$36{,}813 \times 10^9$ MPN in 0.67×10^6 ft³ of daily flow
Streambed Infiltration:	$21{,}351 \times 10^9$ MPN and 0.383×10^6 ft³ are removed through streambed infiltration as calculated in Table 7.0-4
Remaining or Net Load:	15,462 MPN $\times 10^9$ MPN in 0.28×10^6 ft³
Storage Required at 1.25 × net:	0.35×10^6 ft³
Storage Available in Seaford Pond:	0.156×10^6 ft³
Deficit in Storage:	-0.19×10^6 ft³

Removal in the storage provided is calculated as follows:

$$\frac{\text{Storage provided}}{\text{1 day storage required}} = \text{storage or retention time}$$

$$\frac{0.156}{0.35} = 0.45 \text{ days}$$

Using the bacterial die-off equation, the fraction of the coliform load removed during storage is:

Fraction Removed $= 1 - 10^{-k_{10}t}$

where t is 0.45 days and k_{10} is 1.0 as discussed earlier in this chapter

Fraction Removed $= 1 - 10^{-1.0 \times 0.45} = 0.65$

Therefore, the coliform load removed through storage equals $0.65\ (36{,}813 \times 10^{-9} - 21{,}351 \times 10^9) = 10{,}050 \times 10^{-9}$ MPN

Streambed Infiltration Load Removed =	$21{,}351 \times 10^9$ MPN
Storage Load Removed =	$10{,}050 \times 10^9$ MPN
Total Removed =	$31{,}401 \times 10^9$ MPN

$$\text{\% Effectiveness} = \frac{31{,}401 \times 10^9 \text{ MPN}}{36{,}813 \times 10^9 \text{ MPN}} = 85\%$$

5.2.1.2 Energy Dissipation (Gabions). Storage must be considered in terms of its effective volume. As seen from the dye study, between 40 to 80% short circuiting was taking place in a pond during a given storm. The energy in the storm flow causes non-uniform streamlines, high velocities, etc., and it is not unreasonable to expect the same thing to be happening in other ponds as well. Gabions (Figure 5.2-5) are proposed as a way of dissipating this energy, reducing velocities and making streamlines more uniform all across the width of the various ponds. It is estimated that 80% of pond volumes can be made available in this manner, i.e., reduce short circuiting to 20%.

Storm flows are considerably higher than average dry weather flows and can enter a pond at relatively high velocity. The "jet" effect of such an entrance can extend over a large portion of the pond volume. Were it intended to entrain pond waters into the influent jet, an inlet design similar to that found on the typical pond would be considered reasonably effective. Similarly, if the pond outlet is a short weir, the approach velocity will be necessarily high during storm flow conditions. The relatively high velocity in the immediate vicinity of a weir will tend to have an effect over a large portion of the pond volume, extending into the central portions of the pond. The combined effect of the inlet and outlet conditions is to provide for a rapid dispersion of pollutants in the influent flow to the central area of the pond, together with a relatively rapid discharge of water from the central area to the outlet weir. The effective volume of the pond is reduced to a relatively narrow "channel" generated through the center of the pond, with the remaining volume of the pond ineffective for storage purposes.

The desired condition is to have the flow pass through the pond as a "plug" flow, in which all stored water in the pond would be displaced and discharged before any influent flows reached the outlet weir. While it is generally conceded to be impossible to achieve perfection with respect to plug flow performance, it is possible to obtain high levels of performance.

The "jet" effect at pond inlets is probably the most important feature requiring correction, and the desired condition is to have the storm flows enter the pond over a relatively broad "front," at low velocity. Similarly, the outlet of the pond should be arranged so that the influence of the high velocity at the outlet weir is confined to the immediate vicinity of the weir, and is not permitted to affect a significant portion of the pond area. The objective is to get streamlines behaving uniformly over the width of a pond.

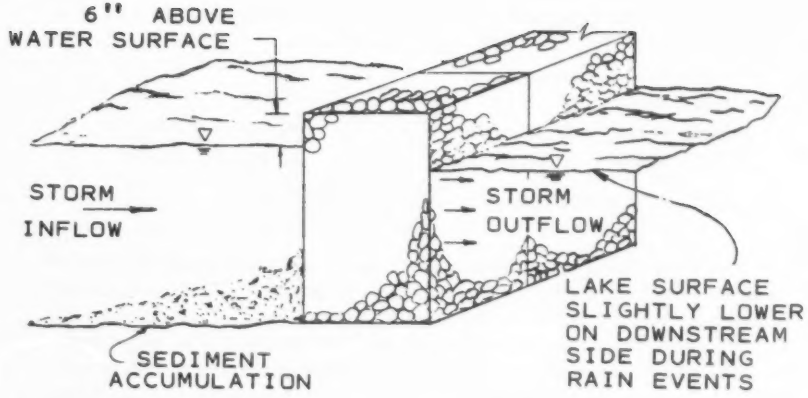


FIGURE 5.2-5 *Schematic detail of a Gabion*

The inlet and outlet conditions described above are similar to the inlet and outlet conditions desired in a settling basin, in which the objective is quiescent sedimentation. Quiescent sedimentation accompanies "plug" flow through such a basin, because the influent flow is introduced at a low velocity and is well-dispersed over the cross section of the basin, with the outlet weir velocity controlled by a relatively long weir length.

The desired inlet control for the typical pond may be achieved by constructing one or more continuous lines of gabions across the inlet at some distance into the pond, with the gabions extending from the pond bottom to about the normal water surface. The gabions, filled with relatively coarse stone in the 4-8 inch size range, will prevent the "jet" action by baffling the inlet flow. As a design parameter, it would be desirable to limit the velocity through the gabion to less than 0.5 ft per second over the gross face area of the gabion. Thus, if the storm flow to be controlled were 100 cfs, the gabion face area should be more than 200 sq. ft. If the pond depth in the vicinity of the inlet were 2 ft, some 100 linear feet of gabion would be required. The objective is to distributed the incoming flow over a broad width at the full depth of the pond.

A similar arrangement may be made at the pond outlet, and the construction of a gabion wall with a maximum gross face area velocity of about 1 ft per second would limit the influence of the high velocity at the outlet weir to the immediate vicinity of the weir. In effect, the gabion wall becomes the interface between the outlet zone and the pond storage volume, and that interface is crossed only by low velocity flow.

In the design of the inlet and outlet gabion baffle walls, it is necessary to provide for maximum storm flows as well as the flows requiring pollutant removal to meet urban runoff control objectives. In general, the urban runoff objectives are achieved by controlling most of the storm runoff, and allowing the high rates of flow accompanying relatively rare storm events to be discharged with less effective treatment. The design of inlet and outlet gabions for a typical pond should also be related to the peak storm flow requirements, since the drainage system must continue to function under such conditions. During peak flow periods, the available head is limited, and velocities are relatively high. Thus, any obstructions to flow which consume energy result in higher upstream water surface elevations than would occur without the obstruction. Gabion walls would constitute such an obstruction and their design should take into account the head and flow conditions prevailing at peak flow. It is quite probable that the design will be dominated by peak flow conditions, requiring additional length of gabion baffle to minimize the head losses associated with the passage of high flows through the gabions. The effect of the increased length of baffle will be to reduce the velocity and improve the effectiveness of the control applied to the more normal rates of influent flow, resulting in some increased efficiency in pond storage characteristics. Similar considerations apply to the gabion wall at the pond outlet, and the design should minimize the additional head requirements associated with peak flows as necessary to satisfy the limiting conditions of the hydraulic profile.

The basis of design for the gabion wall is the relation of head loss vs. flow rate through the gabion void spaces. This relation is given by the following formula, which is applicable for flows of low velocity through a porous medium:

$$Q = KiA$$

Where:
- Q = Flow in cfs
- K = Flow in cfs/SF
- i = Hydraulic Gradient
- A = Gross Area of Gabion = depth × width, ft²

Since the typical gabion is 1 yard in width, the hydraulic gradient term becomes:

$$i = \frac{h}{l} = \frac{h}{3}$$

Where:
- h = Head loss in feet
- l = length of medium incurring head loss "h", in feet

The formula, for a 1-yard wide gabion, then reduces to:

$$Q = \frac{KhA}{3}$$

While gabions have been used extensively in drainage works, the normal usage is as a channel lining or channel wall, in which the hydraulic conductivity of the gabion is an incidental feature.

A study of the characteristics of a porous dike composed of gabions was undertaken by the New England Power Company, with emphasis upon its performance in reducing entrainment and entrapment of marine organisms in power plant cooling water systems. However, some of the experimental data may be used to estimate the hydraulic conductivity of stone-filled gabions. The NEPC porous dike studies were based on continuous flow of salt water, and that the annual volume of flow through the gabion test installation was one or more orders of magnitude greater than that which would occur in an installation designed for control of urban runoff. The NEPC test installation experienced some fouling from entrapment of marine organisms, with the greatest impact during the spring months. Based on observations in late June 1980 of the head losses and flows through a dike section composed of three separate 3-foot wide gabion walls, filled with 8-inch size stone, the value of K in the above formula is 3.03 cfs/sf with a range of 2.33 to 3.80. The degree of fouling which existed during the period of the observations was not recorded, so that the value of K can only be considered an estimate, subject to more accurate determination by experiments using fresh water and the configuration required to control pond inlet velocity.

For design of a gabion wall intended to diffuse pond influent flows, the available head will be one limiting factor, while the geometry of the pond and its inlet will establish other limits. In general, to avoid excessive upstream backwater effects, the head loss through the gabion wall should be minimized; it may be expected that limiting heads on the order of 0.2 to 0.3 feet will not be unusual.

For example, assume a pond inlet with design storm flow of 60 cfs, urban runoff control flow of 30 cfs, and design storm available head of 0.25 ft. The design computation would be as follows:

$$Q = 60 \text{ cfs}; \; K = 3.03 \text{ cfs/SF}; \; h = 0.25 \text{ ft}$$

gabion thickness $l = 3.0$ ft

$$\text{Then Area } A = \frac{Ql}{Kh} = \frac{60 \times 3}{3.3 \times 0.25}$$

$$A = 237.6 \text{ ft}^2$$

Assuming water depth at the gabion of 2.5 feet, the length of gabion wall required is

$$\frac{237.6}{2.5} = 95.0 \text{ ft}$$

The 95.0 ft of wall may be considered a minimum, based on the available head. In some ponds, the 95.0 ft may exceed the pond width, and the gabion wall may be curved or built in zig-zag segments to obtain the required length; in other ponds, the 95.0 ft may be insufficient in respect to pond dimensions, and the pond geometry will control the installation.

A similar computation will determine the length of gabion wall needed to control pond effluent velocities.

Where head loss is extremely critical, the gabion walls may be built 1 ft thick. Such construction will be difficult, and would require a zig-zag arrangement to assure stability against tipping (Figure 5.2-6).

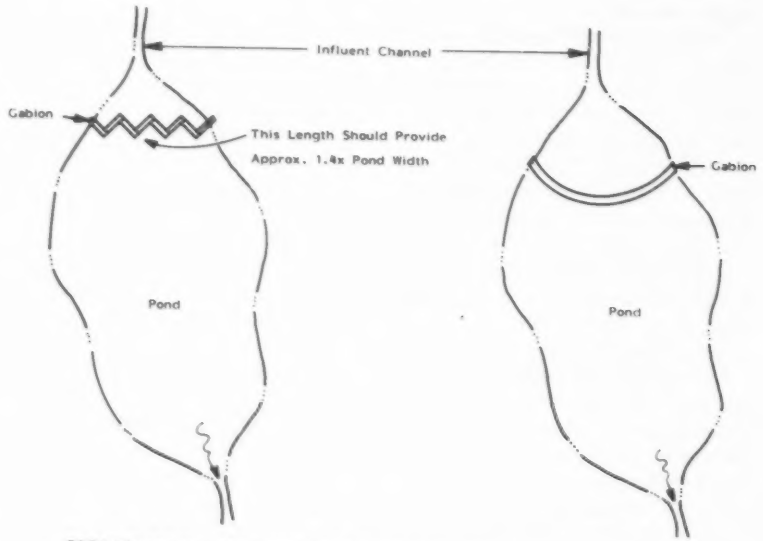


FIGURE 5.2-6 *Alternate gabion placements*

The cost of gabion installation will be relatively moderate in comparison to the benefits to be achieved. Therefore, a much larger surface area of gabion can be installed beyond the minimum calculated using the above formula in order to ensure and improve effectiveness.

Except for the top few inches, the gabion wall wil be, for the most part, out of sight and so may be constructed without the attention to detail required for walls that will be exposed to view. The gabion baskets may be reinforced by additional cross ties, and the fill stone may be placed using a front-end loader or similar equipment.

The gabion baskets will accept settlement without damage, so that extensive foundation work is not required. The construction of the walls may be done most conveniently with the pond partially dewatered, to exposed the bottom at the wall location. The wall area may then be graded and levelled, and the gabion baskets placed. Space for fish passage through the gabion walls may be provided by placing a length of 6 inch pipe in every two to three gabions approximately half way up the wall. Once the fill stone is placed half way

up, the pipe can be laid and the remaining stone placed. Mechanical equipment can be used to place the stone.

In general, gabion construction may be expected to cost $60 to $75 per cubic meter, under normal construction conditions. This cost may be expected to increase, and possibly double due to the need to construct the gabions in a pond bottom with corresponding difficulty of access for equipment and personnel.

The effectiveness of gabion walls may be improved by providing additional gabions, either in the form of a short wall or as intermittent baskets, to dissipate the energy of the influent flow as it enters the pond. In effect, the energy dissipation will permit the influent flows to approach the main gabion baffle at reduced velocity, and will improve the effectiveness of performance of the main wall. The details of each specific installation will be dependent upon the existing inlet conditions requiring improvement. The objective is the conversion of the turbulence associated with high velocity channel or pipe flow to the quiescence of pond storage in the most effective manner.

It should be expected that the filtering action of the gabion as well as its tendency to increase settling by reducing forward flow velocities and making them more uniform, will increase bacterial removal rates. The k_e and k_{10} values noted previously should increase.

During unusually severe storm events, it should be expected that the storm event will generate debris that will be carried to the pond by the storm flows. It is not unusual in a severe storm to find the runoff containing a relatively large volume of leaves, branches, and similar debris. In the past, such material would enter the body of the pond and that which did not settle out in the pond would be discharged over the outlet weir. The gabion walls will tend to act as screens, to collect such debris on the upstream side of the gabions. Following severe storms, it may be necessary to remove collected debris which would interfere with continued functioning of the gabion baffles. Failure to remove the debris will not necessarily negate the performance of the baffle, but may result in flow being directed over the tops of the gabions rather than through the void spaces, with some increase in hydraulic head requirements and some loss in effectiveness in producing velocity reduction.

In many instances the debris is itself a pollutant, or carries adsorbed pollutants. The removal of debris by the gabion walls may thus be looked upon as a mixed blessing; additional pollutants are being collected and concentrated at one location for removal, but the removal effort is necessary. After severe storm events, some general maintenance of the storm drainage system is required in any event, and the need for maintenance of the gabion baffles should be viewed in proper perspective. They will become one additional item requiring maintenance. However, the amount of debris to be removed and the difficulty of that removal throughout the drainage system may well remain unchanged from current conditions without the gabions.

In general, debris trapped by the gabion walls may be removed by dredging and clearing the area upstream of the gabions. Internal fouling of the gabions will require additional cleaning effort. The NEPC porous dike installation was cleaned by backflushing, which proved reasonably effective. For a shallow water pond installation, a similar effect may be obtained by pumping water from the upstream side of the gabion wall over the gabion wall and into the pond or adjacent wetlands. The water level upstream of the gabion would thereby be lowered causing the body of the pond to flush back through the gabion. Alternatively, the pump discharge may be directed into the top of the gabion, at relatively high flow rates, to flush internal fouling.

The use of gabions to improve the storage efficiency of the existing ponds would appear practical, but in situ testing is required to establish the design parameters for this type of installation in order to ensure a pond effectiveness of 80% or more.

When existing storage volumes are not available because ponds are either not located where the load is, or are too small, new or additional storage must be created and this is accomplished by dredging, creating new ponds, or making small ponds bigger.

In calculating the amount of storage required not only must pond volume and short circuiting be considered, but the location of the pond relative to the load must be taken into account. If only 10% of the total flow, i.e., total load, can be routed to a particular pond, the pond can not have an effective volume greater than the 10% of the volume of runoff to be stored.

The use of storage as a control measure, as discussed above, incorporates the concepts of pond modification and energy dissipation both of which were proposed, but in somewhat different fashion, in the original NURP Workplan.

The foregoing discussion of the gabion baffles is based on the use of a continuous baffle across the inlet and outlet of the typical pond. The continuous gabion is a head loss device, and its effectiveness in dispersing flows over the entire face area of the baffle is dependent upon its head loss characteristic.

The objective of the baffle is to prevent high-velocity currents from entering the central portion of the pond. It may be possible, in some locations, to obtain the desired degree of energy dissipation and flow dispersion by means of strategically placed baffles, which would form a discontinuous barrier to flow entering the pond. (*See Figure 5.2-7*).

The objective of a discontinuous baffle arrangement would be to minimize the head loss at pond entry, while retaining the flow dispersion characteristics. Such an arrangement would be particularly applicable where the available head during a high-intensity storm event was critical, or where the pond configuration would permit effective energy dissipation and flow dispersion by a discontinuous baffle.

It should be recognized that once velocities are reduced significantly, it will be difficult to evaluate the effectiveness of the baffle by simple observation. In order to obtain maximum effectiveness, it is desired to induce the stormflows to enter and flow through the pond in the "plug" flow mode. While a sharp reduction in entrance velocity would represent a significant improvement in pond performance, the high degree of improvement desired will not be

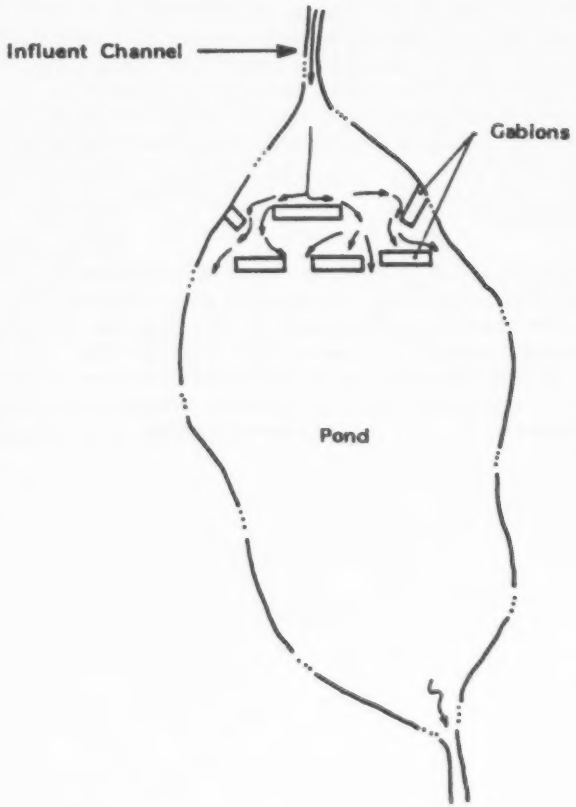


FIGURE 5.2-7 *Alternate gabion baffle placement*

measurable by direct observation of the pond turbulence; dye study will be required to evaluate the effectiveness of both a continuous and discontinuous baffle system.

One feature of a discontinuous baffle system would be a reduced likelihood of clogging due to runoff-borne debris, with a consequent reduction in maintenance requirements. However, it will be necessary to balance the prospective benefits of reduced maintenance against the reduced effectiveness of the baffling arrangement.

5.3 INFILTRATION

5.3.1 Soil Infiltration Rates. Infiltration into the soil of the runoff flow as it occurs accomplishes immediate physical removal of coliform bacteria. The coliforms are simply carried into the soil with the flow. Results from USGS sampling of groundwater underneath recharge basins on Long Island indicate almost total removal of bacteria from stormwater flow through just a small length of travel through the soil. Infiltration or seepage rates are routinely high on Long Island due to the presence of extensive sand and gravel which is extremely porous. As part of the FANS for Nassau and Suffolk, the USGS ran hydraulic tests to determine the infiltration rate through the dry streambed of Fosters Brook. Using the data developed, groundwater hydrologists for the Nassau FANS calculated a seepage rate of 7.4 cu. ft/day per square foot of wetted area at a head of 0.25 ft. This converts to 220 gal/day/SF at 1 ft of head and a hydraulic gradient of 1, or 14.7 inches per hour. Prill and Aronson (1978) in their study on filtration from storm water basins in Nassau County list an infiltration rate of 18 inches per hour at a hydraulic gradient of 1. Since the FANS work for both Nassau and Suffolk shows significant drying of streambeds expected as a result of the sewering program, it is reasonable, given the foregoing, to recognize the opportunity to use these beds to infiltrate stormwater and thereby reduce coliform loads.

5.3.2 Foster's Brook Infiltration Test. Streamflow infiltration was simulated in the Foster's Brook tests conducted by the USGS as part of the FANS effort. Data from this test show 7.4 $ft^3/day/ft^2$ of wetted surface area infiltrating at a stream depth of 0.25 ft. It has been suggested that these data can be used to establish the infiltration rate constant for use in calculating the infiltration rate as a function of stream depth. The data can be used in a more conservative fashion if the unit length of the streambed is visualized as a tank with an orifice at the bottom, given that the streambed is dry. In such a situation, the orifice discharge rate and the infiltration rate are analogous, with the rate being a function of the square root of the stream depth and not directly proportional to it. Given this viewpoint, the above data could be used to establish the infiltration rate constant according to the formulation which is derived from the standard orifice discharge formula:

$q = R(h)^{1/2}$

Where q is the infiltration rate per unit of wetted area
h is the depth of the stream segment, and
R is the orifice infiltration rate constant

$R = q/(h)^{1/2}$

$R = 7.4/0.25 = 14.8$

As a result, this conservative estimate of infiltration rate will vary with average stream depth as follows:

h Average Stream Depth (Ft)	$h^{1/2}$	Infiltration Rate Infiltration Rate Ft³/Day/SF	Infiltration Rate in./hr
0.25	0.5	7.4	3.7
0.5	0.71	10.5	5.3
1.0	1.0	14.8	7.4
1.5	1.22	18.1	9.0
2.0	1.41	20.9	10.0
2.5	1.58	23.4	11.7
3.0	1.73	25.6	12.8

There may be some change in infiltration rate over time, however, the foregoing approach should be conservative enough to compensate for this.

5.3.3 Coliform Removal Analysis. By directing runoff to an infiltration site, coliform removal can be affected. When the runoff rate is less than the site's infiltration capacity, all of the runoff will be infiltrated. When it is larger than the infiltration capacity, only a fraction of the runoff will be infiltrated. If we know the statistical distribution of the runoff, i.e., its magnitude and probability, the fraction that will be infiltrated over the long term can be determined.

Runoff is calculated using the rational formula, $Q_R = CiA$ in which C, the runoff coefficient and A, the contributing drainage area are treated as constants, while i, the rainfall intensity, is recognized as a variable. Changes in rainfall intensity, therefore, produce changes in runoff quantities from a specified drainage area. If it is desirable to infiltrate 90% of the runoff from such an area, the runoff quantity to be dealt with is that produced by the rainfall intensity that occurs 90% of the time. If 80% infiltration is desired, then rainfall intensity occurring 80% of the time must be dealt with, and so on.

Figure 5.3-1 is a probability plot of hourly rainfall intensity for the period of record on Long Island, in which the magnitude of the rainfall intensity is expressed in multiples of the long-term average rainfall intensity. The statistical characteristics of the plot are discussed in Appendix C, Chapter 3.0. This probability plot was used herein to analyze the effectiveness of infiltration as a control measure for runoff. Development of the procedure for doing so is as follows:

The infiltration capacity of a specific site is calculated by multiplying the soil infiltration rate by the soil infiltration area. The Fosters Brook work described previously is one way of estimating the infiltration rate of a dry streambed. The infiltration area is simply the area of the dry streambed for the stream being considered. Conducting a percolation test is a way of estimating the infiltration rate of the subsoil surrounding a leaching basin. The infiltration area of such a basin is the surface area of the disturbed soil around the walls and bottom of the basin. Therefore, infiltration capacity Q_I is equal to the infiltration rate IR multiplied by the infiltration area, IA.

$$Q_I = (IR)(IA)$$

Q runoff is calculated using the rational formula as noted above, $Q_R = CiA$.

When Q_I and Q_R are calculated, the degree to which infiltration occurs is determined by the ratio Q_I/Q_R or (IR)(IA)(CiA The higher the ratio, the more effective the infiltration area is in controlling runoff. Note that in this ratio the infiltration rate, IR, the infiltration area, IA, the runoff coefficient, R, and the drainage area, A, contributing runoff to the infiltration area, are all the result of specific calculations and can be considered constant once calculated. Mathematically,

$$\frac{Q_I}{Q_R} = \frac{(IR)(IA)}{CiA} = \frac{K}{i}; \qquad \text{where K} = \frac{(IR)(IA)}{CA}$$

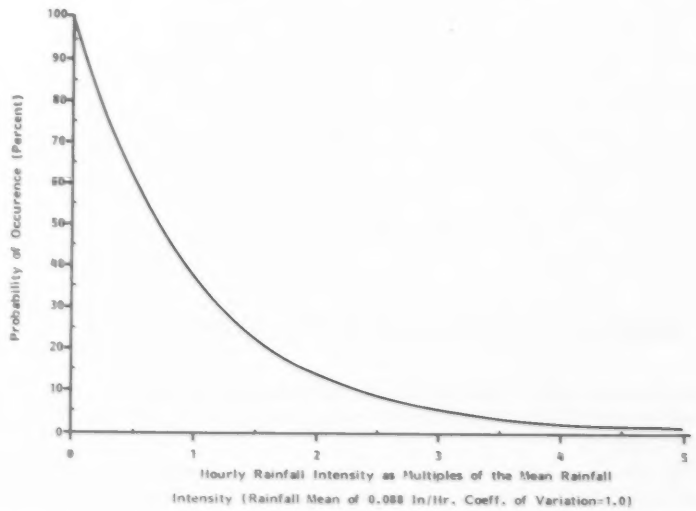


FIGURE 5.3-1 *Probability of occurrence, hourly rainfal intensities for Long Island*

K has the same units as intensity and K/i, which is dimensionless, really expresses multiples of rainfall intensity. If the value of the long-term average rainfall intensity is the value used for i, then K/i expresses rainfall intensity as a multiple of the long-term average intensity. Where K = i, the rainfall intensity is 1 times the average intensity. Where K = 2i, the rainfall intensity is 2 times the average intensity, and so on. Note that K/i is also equal to Q_I/Q_R. Therefore, if the long-term average annual rainfall intensity is the value used for i in calculating Q_R, then the fraction Q_I/Q_R (which is dimensionless) expresses rainfall intensity as a multiple of the long-term average intensity, the same as K/i does. Being able to show that Q_I/Q_R expresses multiples of the long-term average rainfall intensity now allows the probability plot on Figure 5.3-1 to be used as a probability plot of Q_I/Q_R.

Accordingly, Figure 5.3-2 results which is identical to Figure 5.3-1, except that abscissa values are noted as being in the dimensionless units of Q_I/Q_R instead of being noted in the dimensionless units of multiples of mean rainfall intensity. The use of this plot is demonstrated simply by example: Suppose the runoff rate Q_R, calculated for a given drainage area is 50 gpd using the value of the average annual rainfall intensity. If the infiltration capacity Q_I, of the site the runoff is directed to, is 125 gpd, the ratio of Q_I/Q_R = 125/50 or 2.5. Going to Figure 5.3-2 and drawing a vertical line from the abscissa value of 2.5 to intersect the probability curve, relates to a probability of slightly higher than 90%, as determined by drawing a horizontal line from the intersection point to the ordinate. This means that for the case in point, 90% of the long-term runoff will be infiltrated. This is exactly the way the probability plot can be used to determine the effectiveness of the Q_I/Q_R calculated for dry streambeds or leaching catch basins.

Dry Streambed Example

Bellmore Creek East (Data on Table 7.0-3)

Infiltration Capacity Q_I = (IR)(IA)
- IR = 100 gpd/sq. ft. of dry stream bottom
- IA = 348,800 sq. ft of dry stream bottom
- Q_I = (100 gpd/sq.ft.)(348,800 sq. ft.) = 34,900,000 gpd

Runoff Rate Q_R = CiA
- C = 0.21
- i = 0.088 in./hr (long term mean annual intensity)
- A = 2025 acres draining to dry streambed
- Q_R = (0.21)(0.088 in./hr)(2025 acres) = 37.42 cfs

$$\frac{Q_I}{Q_R} = \frac{34{,}900{,}000 \text{ gpd}}{24{,}186{,}478 \text{ gpd}} = 1.44$$

From Figure 5.3-2, percent of runoff captured at Q_I/Q_R of 1.44 is approximately 78%.

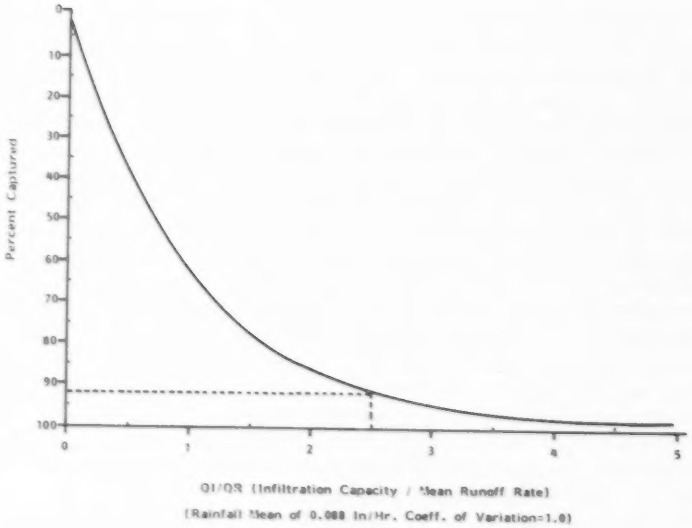


FIGURE 5.3-2 *Average long-term performance of infiltration sites.*

Leaching Catch Basin Example

How many leaching catch basins with 256 square feet of leaching capability are required to remove 80% of the long-term runoff from 100 acres of land with a runoff coefficient of 0.21? Assume a percolation rate of 6 in./hr and no interference from groundwater.

Q_I per basin = (IR)(IA)
- IR = 6 in./hr = 0.5 ft³/hr/SF
- IA = 256 SF
- Q_I = 0.5 ft³/hr/SF 256 SF = 128 ft³/hr/catch basin
- Q_R = CiA
- Q_R = 0.21 • 0.088 in./hr • 100 acres
- Q_R = 1.85 cfs

  1.85 cfs × 3600 sec/m × 6652 ft³/hr

From Figure 5.3-2, Q_I/Q_R must be 1.6 to remove 80% of long-term runoff.

Q_I required = 1.6 Q_R

Q_I required = Q_I per catch basin • number of catch basins = 128 ft³/hr/catch basin • number of basins = 1.6 • 6652 ft³/hr

Number of basins needed = 83

5.3.4 Leaching Catch Basins. A basic feature of the leaching catch basin, favoring its application to developed areas, is its compatibility with existing dense development. The leaching catch basin is a subsurface device, which may be constructed beneath pavement, sidewalk, or lawn areas, without producing significant interference with normal land use. The subsurface nature of the installation, however, precludes construction of large volume basins for economic reasons. The effectiveness of the leaching catch basin is dependent upon a high hydraulic conductivity or infiltration capacity in the soil, and a reasonable depth to groundwater. In general, the high conductivity capacity must extend through the soil mass to allow the leached runoff to discharge freely to the groundwater. The most effective leaching will occur from catch basins which are located above the groundwater table in a porous soil strata. In practical terms, the minimum depth of groundwater to avoid mounding in the catch basin, can vary from about 7 to 12 feet below grade if the soil varies from a coarse material to a fine sand. This point is demonstrated in the technical discussion on mounding presented in Appendix D (see Figure D-3). Further, porous soil located over impermeable layers will not have fully effective leaching capacity, since the porous soil will saturate rapidly due to the "ponding" effect of the impermeable strata.

Information with respect to soil conditions in the peninsula areas has been provided by the LIRPB, and the prospective application of the leaching catch basin concept has been examined in respect to the groundwater and soil information.

The groundwater and soil information provided by Suffolk County is based largely on the information developed in the planning of the Suffolk County Southwest District No. 3, and consists of subsurface boring information obtained to evaluate sewer construction problems.

The data provided by the boring logs and related subsurface investigations has been compiled by the Planning Board staff on New York State Department of Transportation planimetric maps, 7.5 minute series. The compilation indicates areas where the depth to groundwater is from 0 to 3 feet and areas in which depth to groundwater ranges between 3 to 8 feet.

Examination of the compiled groundwater depth data indicates that most of the peninsula areas have groundwater depth too shallow for the application of leaching catch basins.

In general, the leaching catch basins would have major application in the peninsula areas south of Merrick Road and Montauk Highway, since runoff from the shoreline areas would discharge directly to the south shore bays and inlets. North of Merrick Road and Montauk Highway, stormwater may be directed to streams and ponds, and so be subject to other control measures.

In Suffolk County, the peninsula areas in which leaching catch basins would be practical are a very small fraction of the total peninsula area between the Nassau-Suffolk boundary and the Connetquot River. For this portion of the Suffolk County shoreline the shallow depth to groundwater would preclude effective use of the leaching catch basin concept. East of the Connetquot River, groundwater information is available to the boundary between the Towns of Islip and Brookhaven, and approximately 50% of the area of the peninsulas may be suitable for leaching catch basins. The detailed groundwater information is not available east of the Brookhaven-Islip Town boundary, and inspection of the contour maps of the area indicates that there is substantially less fill in the peninsula areas than in those west of Brookhaven. Also, not all of the peninsulas in Brookhaven are developed, and the effectiveness of the leaching catch basins control measure would be limited.

For the shoreline areas of Nassau County, information developed during the planning for Nassau County Sewage Disposal District No. 3 has been provided for review. The groundwater table information is not as detailed as that discussed above in respect to Suffolk County, but the information which is available indicates that the depth to groundwater is similar with respect to the peninsula areas. Further, a substantial part of the peninsula areas in Nassau County consists of fill over marine tidal marsh, which would limit the effectiveness of leaching catch basins due to the impermeable nature of the marine tidal marsh soils.

The Nassau and Suffolk peninsula areas are so limited for the application of leaching catch basins that its use as a control measure is felt to be ineffective.

In order to conduct the necessary evaluation of the leaching catch basin concept, further details and performance criteria were developed and are presented as Appendix D to this report in the event the control measure is suitable in other areas, or is considered suitable for use in those portions of Nassau and Suffolk County where the depth to groundwater and related soil conditions are suitable.

5.3.5 Low Level Stream Dams. The relatively flat hydraulic profile of Long Island streams operates to control velocity effectively. At a typical slope of 1.5 ft/1000 ft, a stream 10 feet wide by 1/2 foot deep would have a velocity of about 1.3 ft/sec, and increasing the depth to 2 feet in the same channel would increase velocity to about 2.8 ft/sec. The corresponding flows would range from 6.5 cfs to about 56 cfs, so that increasing the velocity by a factor of 2.15 is accompanied by a flow increase at a ratio of 8.6. For the physical conditions to be encountered on Long Island streams, the velocity ranges should not have any significant effect on the leaching capacity of the streambeds. Table 7.0-3 presents a summary of the physical data for the Long Island streams, indicating typical dimensions of depths, widths, slopes, etc. The FANS for Nassau and Suffolk counties indicate that approximately 142,000 lineal feet of streambed will suffer cessation of normal flows as a result of lowering of the groundwater table, and these reaches of streams will be available for leaching of stormwater runoff as an effective measure for the control of coliform loads. Dry streambeds are expected to be a chronic condition, but in particularly wet years they will be somewhat less prevalent, and in particularly dry years they will be somewhat more prevalent.

Although the streambeds are relatively flat in cross section, extremely low

flows would not normally cover the entire streambed, so that under the flows to be anticipated in a less severe storm a substantial portion of the available leaching area may not be submerged under natural streambed conditions. Accordingly, it is proposed that a 12 × 12 stop log or some other low level obstruction be placed in the stream at about 100 foot intervals to assure ponding of the water upstream over the entire width of the dry streambed (Figure 5.3-3). The limiting capacity of the streambed to infiltrate runoff will be reached when flow is overtopping all stoplogs in the stream. This limiting capacity has been estimated for each stream and is presented in Table 7.0-4. Detailed design of the stop logs or other obstructions may indicate some variations possible in overall dimensions and spacing given specific site conditions.

The stop logs should be checked periodically, perhaps twice a year, to observe their general condition. Other than this, little or no maintenance should be required. Sediment that will tend to deposit behind these low level dams should not be a concern since it should be scoured out during the really high storm flows that occur from time to time. Costs are estimated at $500 per installation; $250 for material, $50 for transporting and handling; and $200 labor for installation.

It should be understood that the function of the low level stream dams is the shallow ponding of water upstream of the dam, to allow submergence of the entire streambed. By submerging the entire streambed, the quantity of runoff leached through the streambed will be markedly increased. Figure 5.3-3 shows the detail which would apply using timber as the base material for the low level dam. Other materials may be used to produce the desired effect. For example, a low level dam composed of loose stones or cobbles weighing about 100 pounds each, and with the interstitial spaces grouted with concrete, would function similarly. Where stream velocities are relatively low, the dam function could be obtained by regrading the stream bottom at the downstream end of flat reaches, to require submergence of the flat reach upstream as water passes over the obstruction.

In some instances, the low level dam may be formed by using materials in the streambed, such as stones or cobbles with dimensions on the order of 6 inches, assembled in a band several feet in width crossing the entire streambed. While such a loose-cobble dam would not exert the same degree of control as the detail shown in Figure 5.3-3 or the mortared-stone equivalent, it would provide significant ponding upstream due to the hydraulic losses required for the streamflow passing the obstruction.

It should be understood that the objective is submergence of the entire streambed during storm runoff periods, and natural materials existing in the streambed may be arranged to produce the desired effect.

Final design and placement of low level stream dams should take into consideration the location of suitable floodplain areas.

5.3.6 Wetlands. The use of wetlands as a control measure to remove coliform bacteria was investigated. A long-term study of a wetland to remove

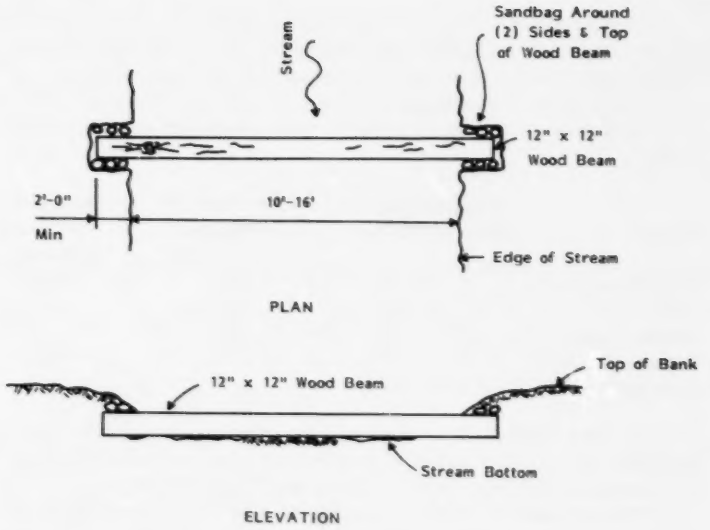


FIGURE 5.3-3 *Low level dam for use in streams.*

various pollutants, including coliform bacteria, was reported in the Journal of the Water Pollution Control Federation (February 1978). The study was supported by EPA, the State of Wisconsin, and the Regional Planning Commission. The wetland is known as Brillion Marsh and Spring Creek, which enters it, receives waste effluent from the overloaded treatment plant serving the City of Brillion, Wisconsin (population 2588). Most of the vegetation reported for this wetland has also been identified for Long Island.

The portion of the wetland area studied is reported as being 156 hectares in area; as having no identifiable stream channel running through it; and as having an average water depth of 0.5 m and a volume of 7.8×10^5 m³. The drainage area contributing to the wetland is 49.7 km²; 31.3 km² contributing to Spring Creek which receives the Brillion waste effluent and 18.4 km² from other streams. Using data from June 1974 through June 1975, the following observations were made:

1. The log average daily load to the wetland was 1.2×10^{13} MPN/day.
2. The log average daily load leaving the wetland was 9.1×10^{11} MPN/day producing an average reduction of 92%.
3. The residence time of the wetland was 31 days.
4. Given the area of the wetland as 385 acres (156 hectares) the loading to the wetland was 3.12×10^{10} MPN/day/acre of wetland.

The percent reduction in load is of the order desired for use in plan formulation for Long Island. However, the requirement for a long detention time and the low loading per acre led to the conclusion to eliminate wetlands from further consideration. The loadings and drainage areas of the following streams, which had been suggested as possibly having wetlands potential, were considered.

Stream	Daily Coliform Load (MPN/Day)	Total Drainage Area (Acres)	Wetland Area Required (Acres)
Santapogue Creek	1.37×10^{14}	2957	4400
Carlls River	2.13×10^{14}	4560	6800
Willets Creek	4.67×10^{13}	990	1500
Orowoc Creek	1.22×10^{14}	3048	3900
Champlin Creek	7.63×10^{13}	2277	2450

Clearly, the wetlands area required is out of balance with the drainage area available. Even if just a portion of a stream's load were to be handled the land required would still be excessive, given that a long ($\approx$ 31 day) detention period would be necessary. The average detention time of 31 days calculated from the reported data appears to be rather long and corresponds to a very low overall bacterial removal rate. No explanation in the experimental write-up was given for this. There may have been some environmental factor that retarded bacterial removal or die-off, and/or there may have been coliform contributions from the marsh itself which added to the total coliform load. However, the results indicate that should conditions on Long Island be similar to those of the experimental site, as the similarity in vegetation suggests, wetlands would be inappropriate to use as a measure for coliform removal. Site specific testing on Long Island would be necessary for further evaluation of this control measure. Those identified by the Suffolk County Department of Health Services appear reasonable.

5.4 INSTITUTIONAL CONTROL MEASURES

Institutional, or non-structural, control measures were major components of the non-point source control program proposed in the "208" study, and for the control of urban runoff, they continue to be. The "208" data indicates that loads from both dogs and ducks are dominant and elimination, or more likely, reduction of these loads should be sought through institutional means. This is especially true in the southern shore areas of the two counties where runoff drains directly to the bays and tidal areas rather than to freshwater streams.

Of particular applicability, with regard to coliform reduction and control in urban runoff, are such institutional measures as those dealing with animal waste control, preservation of stream corridors, and the prevention of increased runoff loads in developing areas.

5.4.1 Animal Waste

5.4.1.1. Defining The Problem. The "208" study found that urban runoff containing dog and other animal waste was responsible for the then recent closures of shellfish growing areas. Data taken at the surface water in situ control sites in the NURP study support that conclusion. Two sources of animal waste, dogs and waterfowl, appear to be of particular significance in contributing coliform in the NURP study area.

The estimated bicounty dog and wildfowl population during the "208" study was about 425,000 dogs and 100,000 wildfowl. A wildfowl count taken at the more important ponds during the NURP study tallied about 14,000, of which about 4,200 consisted of ducks and geese whose populations are supported largely by public feeding. Although this bird count was not a complete study of waterfowl along the south shore it is indicative of the large waterfowl population that inhabits Long Island.

The "208" study cited the example of Roslyn Park Pond where a large (over 500) duck population created such high levels of coliform at the outlet that swimming at Hempstead Harbor beaches downstream of the pond was jeopardized. (The problem was taken care of by transplanting the majority of the ducks to other ponds and by chlorinating the pond effluent).

Table 5.4-1 enumerates the coliform characteristics of dogs, wild ducks and geese as compared to the coliform contributed by an acre of residential land. Based on these estimates, it is apparent that animal waste may in fact be contributing all or almost all of the fecal coliform load attributed to runoff from the landscape. Although certainly not all coliform from animal waste enters surface waters, the relative importance of these sources of coliform become more important in small drainage areas which support disproportionately large animal populations, around ponds where waterfowl are artificially sustained by public feeding and in areas draining directly to the bays and tidal portions of streams (generally below Merrick Road and Montauk Highway).

Table 5.4-1

COLIFORM WASTE CHARACTERISTICS OF DOGS, DUCKS AND GEESE AS COMPARED TO RESIDENTIAL LAND[a]

	Manure (g)/Day	Fecal Coliform (MPN) Per Gram	Fecal Coliform (MPN) Per Day
Dog	227g/Day	18×10^6 MPN/g	4×10^8 MPN/Day
Duck	336g/Day	32.7×10^6 MPN/g	11×10^8 MPN/Day
Goose	1498g/Day	32.7×10^6 MPN/g	49×10^8 MPN/Day
Acre of Residential Land			1×10^8 MPN/Day

[a] Estimates derived from "208" Study

As seen in Table 5.4-2, further evidence of the importance of animal waste coliform contributions is found in examination of the fecal coliform/fecal streptococcus (FC/FS) ratio of runoff sampled at the in situ sites. The mean FC/FS ratio at each site is clearly well below the FC/FS ratio for man and certainly points to an animal waste origin of the fecal bacteria.

Table 5.4-2

IN SITU CONTROL SITES
FECAL COLIFORM/FECAL STREPTOCOCCUS RATIOS

Site	FC/FS Ratio[a] Mean	Range
Bayville (influent)	.08	.01- .16
Unqua Pond (influent)	.38	.10-1.23
Energy Dissipator & Street Sweeping (runoff)	.71	.04-1.82

[a] FC/FS Ratios:
Human: 4.4
Duck: 0.6
Dog: 0.002

5.4.1.2. Control Measures. The "208" recommended a number of institutional measures for animal waste control as part of its areawide recommendations for non-point sources that were considered to be implementable as well as cost effective. Those recommendations dealing particularly with dogs and waterfowl are still appropriate for the NURP study and are summarized below.

- Repeal ordinances that require the curbing of dogs to reduce dog waste pollution. Curb laws encourage dog defecation on impervious surfaces which are flushed into surface waters by the next storm.
- Urge the adoption of dog clean-up ordinances.
- Promote dog sterilization programs in order to limit the growth of the dog population.
- Provide a continuing public information program to make dog owners more aware of their responsibilities.
- Eliminate White Pekin ducks and their derivatives from inland ponds that are not part of a farm operation.
- Prohibit the sale of White Pekin ducks as pets within the bi-county area.

As a result of the NURP study, the following is suggested as an addition to the above list of "208" recommendations:

Waterfowl - Enact ordinances prohibiting the feeding of waterfowl in and about lakes and ponds.

The "208" study notes that Canada geese are changing their migration habits and becoming year round residents of Long Island. This is an indication of the extent of the impact associated with public feeding of waterfowl. If localities do not wish to comply with adopting an ordinance, an alternative would be to require that streams be diverted around such ponds since ponds without runoff inflow will have little outflow during storms. This may be an expensive option for a locality, but nevertheless a legitimate one in that local jurisdictions are responsible for treatment and disposal of their own wastes, unless they are part of a broader regional entity created for waste handling purposes. The foregoing would require communities to either eliminate public feeding in their communities which is a causative factor in producing coliform wastes, or keep the waste in their community through the elimination of pond overflows.

Dog - Enact ordinances zoning the tidally drained shoreline areas generally south of Merrick Road, Sunrise Highway and Broadway in Nassau and Montauk Highway in Suffolk, as areas requiring dog owners to clean up the fecal material deposited by their dogs. Structural alternatives to handle the problem contributed by dogs resident in these areas will be expensive, since there is no way to route the surface drainage from these areas into stream corridors where loads could be handled by other means. The proximity of these areas to the shoreline and shellfish beds requires that such zoning be affected. The receiving water is too sensitive to their discharges.

Enforcement of a dog ordinance should receive more attention if it is confined to shoreline areas as opposed to being adopted for widespread application. Residents of shoreline areas may feel that they are being unnecessarily singled out for attention. But nevertheless they reside along a rather unique and sensitive area of the island, the shoreline.

In order to further implementation of the ordinance, dog owners in the shoreline areas should be required to own a dog scoop to clean up after their pet, and evidence of ownership of an implement should be made a condition of the annually issued dog license. In addition, the ordinance should stipulate that anyone walking a dog in the shoreline area must carry one of these scoops. Adoption of a dog ordinance beyond the shoreline areas, in an attempt to be "equitable" so that all are treated the same, goes beyond the need for such and will dilute the effectiveness with which the ordinance can be enforced. It is further believed that calling for voluntary action on the part of shoreline residents will be ineffective.

If dog ordinances are adopted along the lines noted above, a reasonable time should be allowed for judging their effectiveness. Results, in terms of improved water quality, should be evident within one to two years after adoption. If such results do not materialize within one to two years after implementation of the ordinance program, the approach should be abandoned and a decision made to either accept the condition of bacterial pollution of the south shore waters, or go forward with a street sweeping program if testing shows it to be an effective control measure.

If street sweeping is pursued, revenue to finance and maintain it could be sought to some degree from dog owners through the dog licensing program.

5.4.2 Stream Corridor Preservation. Retaining undeveloped stream corridors can assist in future urban runoff control by preserving land areas. These areas would be used for future implementation of control measures in the event that control of runoff loads from future residential development fails to occur.

The institutional means for maintaining the integrity of stream corridors for these purposes are, or can be made, available at the state and county level of government. The New York State Department of Environmental Conservation has permitting requirements for any construction performed in or near streams classified as A,B,C or C(T), which would cover many of the streams on Long Island.

A mechanism for stream corridor control presently unavailable in the bicounty area is a stream control law such as the Westchester County Stream Control Law enacted in the 1950s. This ordinance developed specifically for the purposes of floodway protection, requires a special permit be issued by the County Department of Public Works for construction within 100 feet of certain designated stream boundaries. Westchester defined this boundary on a stream by stream basis by assuming a variable set back (dependent on stream characteristics) from surveyed property lines along the streams. This ordinance, although not strictly prohibiting development, does through its permit requirement, maintain floodway integrity by specifying construction procedures to be used for work in stream corridors. A similar ordinance could be formulated for the bicounty area that has as its main purpose urban runoff control rather than floodway maintenance.

5.4.3 Development Ordinance. As areas continue to be developed on Long Island, primarily in Suffolk county, urban runoff will increase and so will the total bacterial load. As seen from the discussion of loading factors in Chapter 4.0, and referring back to the "208" results, concern should be felt for medium density residential development. This land use has the highest loading factor, and it is the land use which can be expected to be more intensely developed than any other. Projections have been made as to the extent of such development but its precise timing and location is of course uncertain. It is suggested therefore, that those responsible for such development be required to develop plans for control of the runoff originating therefrom. This has become a common practice in many communities where control of runoff quantities have been necessary in order to deal with flooding impacts. These communities have developed ordinances requiring developers to include runoff control as part of their development. The same concept is valid for control of the pollutional aspect of runoff. The techniques of infiltration and storage presented in this study are reasonable for use in new development, and therefore could be referred to in ordinances adopted by Long Island communities. Developers should be allowed some degree of freedom in selecting the precise control measure to use, but local ordinances should be adopted now requiring such control.

Based on the foregoing discussion, the following control measures are considered useful in respect to the conditions to be encountered in the Long Island area:

Physical Measures:
- Pond Storage
- Streambed Infiltration

Institutional Measures:
- Reconsideration of Shellfish Standards
- Animal Ordinances
- Stream Corridor Preservation
- Development Ordinances

5.5 GENERIC ENVIRONMENTAL ASSESSMENT STATEMENT FOR URBAN RUNOFF CONTROL MEASURES

Each of the control measures described in Sections 5.2 through 5.4 of this Chapter has as its primary objective the reduction of coliform bacteria in urban runoff such that shellfish beds in the south shore bays can be certified for harvesting. Meeting this objective is the major beneficial impact of each measure. Other impacts of these measures associated with their installation, operation and maintenance are described in the following paragraphs. This discussion of impacts is generic, emphasizing major impact categories in relation to the entire study area.

5.5.1 Physical Measures. The physical control measures described previously include the operative mechanisms of storage and infiltration, for die-off and physical removal of coliform bacteria, respectively, in storm runoff. Short-term impacts of physical control measures can generally be associated with their installation and maintenance while long term impacts can generally be associated with their operation.

5.5.1.1 Storage. The physical means to provide more time for coliform die-off revolve around pond modifications to increase effective storage and include placement of gabions at inlets and outlets, dredging of existing ponds, extension of existing ponds and creation of new ponds.

5.5.1.1.1 Gabions. The installation of gabions may or may not require limited dewatering of portions of the pond depending on the depth of the water where the gabions are to be placed and will require the use of some heavy equipment such as a front end loader working in and around parts of the pond. Impacts associated with this installation may include:

- temporarily impaired or prohibited use of the pond for recreation because of construction activities,

- temporarily lowered water surface if some dewatering is required,
- temporarily deteriorated pond water quality, particularly in the form of increased turbidity, as a result of resuspension of pond sediment from earth moving activities,
- temporary erosion of pond banks where heavy equipment is operated, and
- elimination of some pond shoreline vegetation as a result of movement of heavy equipment.

With the exception of restricted pond use and possibly lowered water surface, the other installation impacts can be mitigated to various degrees by adherence to strict construction guidelines such as limited and defined construction right-of-ways to minimize damage to vegetation and erosion losses, use of erosion controls such as straw rip-rap on shorelines, and site restoration including vegetation plantings.

As previously discussed, gabions will function as energy dissipators slowing the flow through the pond. This reduction in flow will provide additional time for bacterial die-off in the pond and will also increase sedimentation on the upstream side of the gabion. In addition, it may tend to accelerate the processes of eutrophication already occurring in Long Island ponds and lakes by providing additional time for nutrient uptake by algae and other aquatic vegetation and increased accumulation of nutrients in sediments. The significance of any acceleration in eutrophication caused by urban runoff control measures is uncertain. As described in the Nassau and Suffolk FANS, the lakes and ponds are generally in such a state of eutrophication that any actions taken which might tend to accelerate the eutrophication process may be obscured. The uncertainties associated with this impact could be evaluated by instituting a lake monitoring program.

Because the gabion acts as an obstruction to flow, debris such as branches, leaves, and paper will tend to accumulate at its face. Although large storm flows will tend to wash away much of the debris, it may be necessary to periodically remove the accumulations. In addition, the sediment buildup may require dredging as a maintenance procedure once a year or even more frequently. Maintenance requirements of gabions are difficult to estimate, since gabions have not been used before as proposed herein. If frequent maintenance of gabions is required maintenance costs will be high. However, this determination should await the results of in situ testing. The impacts of maintenance dredging for the gabions would be similar, though on a considerably smaller scale, to the impacts of dredging to increase pond volume as discussed in the next section. These maintenance activities are necessary to insure flow through, rather than over, the gabion. Gabion design and placement should be such that high storm flows are not restricted to ensure no expansion of the storm floodway.

5.5.1.1.2 Dredging. Dredging as an urban runoff control measure is being suggested for ponds whose location in their stream system does not allow for sufficient effective storage of storm runoff. Dredging accumulated sediments, and in some cases virgin soil material, will increase the storage capacity of a pond thus providing additional detention time for bacterial die-off.

Instituting a dredging program in any particular pond may result in a number of construction related impacts similar to though more extensive than those described previously for installation of gabions. The amount of material to be dredged and the depth of water in the pond will define the level of impacts to be felt from dredging. The measures to mitigate these impacts would be the same as those described for gabion installation except that the required mitigation would probably be more extensive both in terms of time and areal coverage.

Disposal of the dredged materials must be accomplished in an environmentally acceptable manner depending on the composition of the material. It is unlikely, based on present surface water quality that any dredged material would contain significant concentrations of toxic substances. However, to ensure proper disposal of the dredged material, samples of pond sediment should be analyzed for grain size distribution and for toxic and organic constituents prior to dredging to determine its proper disposal route. If for example, it is found that the sediment consists primarily of sands and gravels, as is the case in stream beds, the sediment may be suitable for construction fill. If, however, the sediment consists of organic mucks it may require disposal in a suitable landfill site or may have to be barged to an ocean disposal site.

Maintenance dredging of a pond to retain a desired depth subsequent to the initial dredging program will be relatively infrequent since it is envisioned that a pond dredging program would include gabion placement at pond inlets. Therefore, what regular maintenance dredging would take place would be on the upstream side of the gabions where sediments would now tend to accumulate. Pond-wide redredging will probably not be necessary for many years if at all. A pond monitoring program designed to measure accumulated sediment at various portions of the pond may be used to schedule any necessary maintenance dredging.

5.5.1.1.3 Extension of Existing Ponds and Development of New Ponds. In stream systems having no ponds or ponds too small for effective storage of the urban runoff from the contributing drainage area, new ponds can be created or existing small ponds can be extended. Sites selected for the location of new or extended ponds would of course have to be vacant and preferably be under public domain. Ideally, the site would be within an existing park or preserve. Design of the new or extended pond would have to include flood routing to ensure that future flood flows can be contained in acceptable floodplain areas.

The temporary construction impacts discussed previously for both gabion installation and pond dredging would also occur during the construction of a new or extended pond. These impacts included: temporarily impaired or prohibited use of the stream (or existing pond) for recreation, temporarily lowered

water surfaces and/or diversion of stream channels, temporarily deteriorated surface water quality, and temporary erosion of stream and pond banks. The mitigation measures described previously for gabions and dredging are also applicable here.

Aside from providing for additional time for coliform die-off in urban runoff, the major long-term impacts of a new or extended pond could include:

- elimination of the present uses of the land designated for the new or extended pond,
- elimination of existing vegetation and associated wildlife at the new site,
- creation of new water surface and associated aquatic habitats that may experience large and rapid changes in water levels,
- possible increases in recreational use in or around an expanded pond, and
- possible acceleration of eutrophication at an expanded pond.

Depending on the present use and ownership of a site proposed for a new or extended pond, elimination of the present uses of the site may be met with various degrees of acceptance by elected officials and the general public, particularly those nearest the selected site. As mentioned earlier, the ideal site in this respect would be an undeveloped tract within an existing park or preserve.

Assuming that some undeveloped vacant site is selected then dredging and construction at the site will eliminate existing vegetation and its associated animal habitats. Since a selected site will be near an existing stream or pond, care will have to be exercised to minimize destruction to the more sensitive and areally limited habitats such as moist red maple swamps. Construction in a managed parkland would result in significantly fewer adverse ecological impacts, and final site selection should be geared to such a land use.

Since the primary objective in creating a new pond is control of urban runoff, what new water environment is created by such a project may, dependent on its location in the stream system, experience fairly large and rapid fluctuations in water levels. Thus a new pond may have little opportunity to establish or support any diversity of aquatic habitats other than such tolerant species as reed grasses. In addition, a new pond may not be able to provide any substantial opportunity for water based recreation and may be perceived as aesthetically undesirable and/or a community safety hazard as is the perception of many upstream recharge basins. These types of impacts can be significantly mitigated by locating any new ponds as far downstream as possible. In this way the higher groundwater elevation located toward the south shore area will provide baseflow to the pond mitigating large water level changes yet still retaining its urban runoff control function.

Extending an existing pond may accelerate ongoing eutrophication at the pond by providing additional time for nutrient uptake and settling as described previously in the discussion of dredging as a control measure. The significance of this acceleration is uncertain in light of ongoing eutrophication. Extending an existing pond may provide new or increased opportunities for water oriented recreation assuming that baseflow water levels in the extended pond are adequate to maintain such recreation.

5.5.1.2 Infiltration. The infiltration mechanism described previously for urban runoff control is infiltration through dry stream beds enhanced by placement of low level dams along the stream corridor. This measure has as its major long-term beneficial impact a reduction in coliform bacteria brought about by bacterial die-off and physical removal by the soil.

5.5.1.2.1 Infiltration through dry stream beds. The Nassau and Suffolk FANS predict that more than 142,000 linear feet of presently flowing streams in the bicounty area will become dry as a result of groundwater declines caused by ongoing sewering. Storm runoff in the future will therefore have the opportunity to infiltrate into these dried stream beds. This infiltration can be enhanced by the placement of low level dams along the stream corridor, about every 100 feet, in order to ensure exposure to the entire stream bed and to provide additional head for infiltration.

Placement of these low level dams, which will measure about 12 inches wide by 12 inches high and will extend over the entire width of the stream, may result in such minor temporary adverse impacts as erosion where the dam is notched into the streambank. This sort of impact can be mitigated by adherence to construction techniques that limit erosion and restore streambanks.

The total quantity of urban runoff that could infiltrate through dry streambeds, e.g., about 35% of present runoff flows in Nassau, is small when compared to the expected extent of groundwater declines as a result of sewering. Therefore, the major long-term impact of streambed infiltration of urban runoff would be to groundwater quality. Insight into the impacts to groundwater quality can be gained by examination of the in situ testing of the USGS recharge basins. Provisional data from these sites indicate that although there are substantial reductions in coliform concentration there is as yet no clear indication of the fate of other urban runoff constituents such as heavy metals, chlorides, or total nitrogen. With the exception of nitrogen and chlorides, there appears to be some reduction of these constituents under almost all storm conditions. The uncertainty of the fate of these pollutants should be clarified when additional recharge basin data is available.

Flooding beyond present floodplain boundaries should not be of major concern since the dams are of such small heights, and since the final design and placement of these low level dams should take into consideration the location of suitable floodplain areas.

Maintenance of the low level dams is expected to be minimal and primarily involve removal of debris and sediment that may tend to collect on the upstream side of the dam. The impact associated with such maintenance will relate to the selection of a suitable disposal site for the materials collected. In all likelihood the stream corridor itself will present such a site.

5.5.2 Institutional Measures. The institutional urban runoff control measures being recommended include adoption of animal ordinances, stream corridor preservation, development ordinances, and reconsideration of shellfish standards.

Implementation of the dog and waterfowl ordinances described in Section 5.2 will have a beneficial impact not only in the form of reduction of coliform bacteria entering urban runoff, but also a reduction in other animal waste loads such as BOD and nitrogen. It is likely, however, that portions of the affected public and perhaps some elected officials may take exception to implementing such ordinances which may be perceived as discriminating against dog owners and waterfowl feeders. A concerted educational program conducted with the cooperation of all levels of government would probably be the best approach toward mitigating anticipated adverse public reaction.

Enactment of statutes, at a county or more local level, for the preservation of stream corridors may accrue benefits not only in improved runoff quality but also in such areas as flood and erosion control, wetlands preservation, etc. The implementation of such a statute may be new for the area but should not be too difficult to institute given existing stream laws.

Development ordinances are certainly not new and the implementation of one directed at controlling the quantity and quality of urban runoff should not be particularly difficult. Prevention of an urban runoff problem early in the design and construction of new developments will eliminate the necessity of controlling a future problem.

Perhaps the most difficult institutional measure to implement may be changes to standards for shellfishing certification. The number of Federal and state agencies involved in rulemaking and enforcement of public health standards for shellfishing precludes change in such standards in the near future even if sufficient scientific evidence can be gathered to warrant change. Nevertheless, there is no reason why such change can not be pursued in the meantime.

Appendix E

Waterfowl

1. The Effect of Waterfowl Activities on Pond Water Quality
   Nassau County Department of Health, 1981.
2. *Report on Waterfowl Count on the South Shore of Nassau and Suffolk Counties.*

Preceding page blank

THE EFFECT OF WATERFOWL ACTIVITIES ON POND WATER QUALITY

I. INTRODUCTION

A variety of waterfowl inhabit the freshwater wetlands of Nassau County. Waterfowl species such as Canadian geese, mallards, seagulls, and swans abound in these intricate wetland systems. Waterfowl populations vary from wetland to wetland, and seasonal variations of populations are common with some species.

A typical freshwater wetland system consists of one or more areas which are either permanently covered by shallow water (less than 6 feet deep) or subjected to periodic flooding by surface or ground waters. The waterfowl usually congregate in and about these water-covered areas, (ponds and/or lakes) feeding mostly upon bottom dwelling plants and excreting their bodily wastes into these waters.

It has been suggested that these particular activities of the waterfowl have an adverse effect on the water quality of the wetland system they inhabit. This suggestion prompted the Nassau County Department of Health to monitor three wetland areas for any changes in water quality that could be attributed to a waterfowl population. This report will discuss the program conducted for monitoring these waters and present the water quality data collected from the three wetland areas. An evaluation of the water quality data will be presented with respect to the possible degradation of these waters by waterfowl populations.

II. THE MONITORING PROGRAM

Three wetland areas were chosen for the monitoring program. They are as follows: The Massapequa Reservoir, Unqua Pond, and the Tackapausha Pond of the Tackapausha Preserve. These three sites were chosen primarily for their relative waterfowl populations, ranging from a small population at the Massapequa Reservoir, averaging 25 birds; a medium population at Unqua Pond, averaging 100 birds; and a large population at Tackapausha, averaging 380 birds. Other factors considered in selecting these sites were:

- their proximity to each other (see Figure 1),
- their similar drainage patterns,
- accessibility to influent and effluent drainage location.

A description of each site is presented in Section III.

Also considered was the area surrounding each wetland, which was primarily residential in each case. A primarily residential area surrounding each wetland reduced the possibility of water contamination by industrial sources. Contamination of these waters by industrial chemicals or other such materials would have significantly altered water samples gathered in those areas, affecting the monitoring program results.

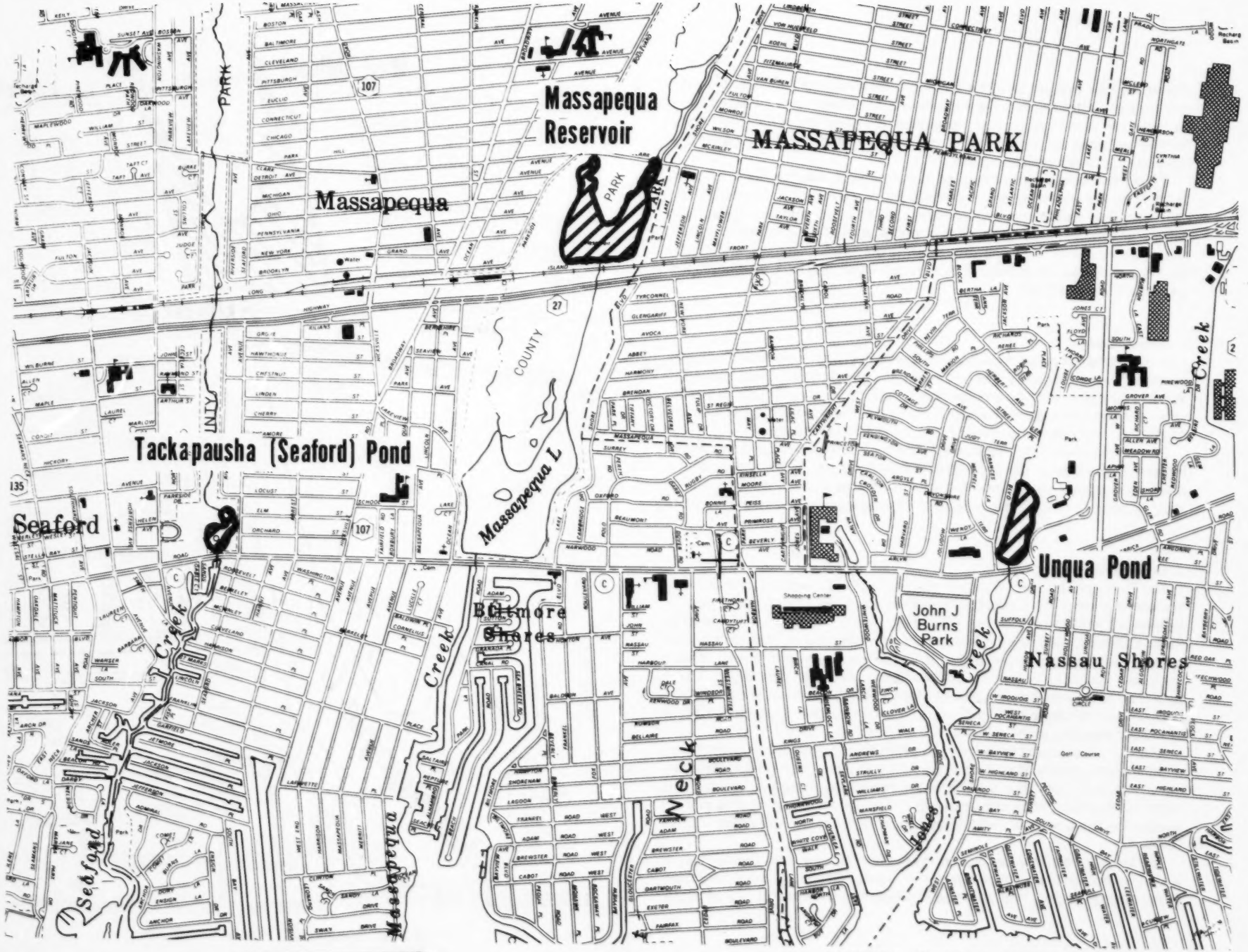
Monitoring of the three wetlands was conducted over a ten-month period, from November 1979 to August 1980, and consisted primarily of collecting water samples for bacterial (total and fecal coliform, fecal streptococci) and chemical (nitrogen containing compounds) analyses. The samples were collected during both dry and wet weather days. A dry day is considered one in which a rainfall event did not occur or occurred 72 hours prior to that day. A wet day is a day in which a rainfall event does occur (at least 0.1 inches of rain) and includes all days within 72 hours after the rainfall event. From November 1979 to May 1980, chemical samples were collected three times per week from each site. Samples were collected less frequently from June 1980 to August 1980 due to increased bathing beach and marine surface water monitoring performed by the Health Department.

When possible, a count of the number of species of waterfowl present at each site was taken at the time of sampling. It became difficult to make an accurate count when a large number of birds were present at a particular site, due to their constant movement. Therefore, an approximate count of the number of waterfowl was made when populations exceeded about 50 birds (this was especially true at the Tackapausha Pond where populations regularly ranged between 150 and 500 birds).

III. SELECTED WETLAND SITE DESCRIPTIONS

Massapequa Reservoir

The 16-acre Massapequa Reservoir is the next-to-last pond located between the main stream channel of Massapequa Creek and Massapequa Lake (see



Reproduced from best available copy.

FIGURE 1 *Overall map showing waterfowl study sites*

Figure 2). Two influent streams enter the reservoir from the north at the eastern and western ends of Clark Boulevard. The effluent is discharged at the southern end of the reservoir at a point near the Long Island Railroad tracks. Residential areas surround most of the reservoir and the remainder of the Massapequa Creek wetland system.

The number of waterfowl observed at the reservoir was usually small compared to the area of the reservoir. The average number of birds counted during each sampling period was approximately 25. This would be equivalent to a density of approximately 1.6 waterfowl per acre. Since the mallards, geese, and other waterfowl inhabiting these waters are bottom feeders, the greater depths of the reservoir probably discouraged larger numbers from using this area as a feeding station.

Unqua Pond

Unqua Pond is located in the Town of Oyster Bay, approximately ¾ of a mile south of Sunrise Highway and just north of Merrick Road. The pond is 5.5 acres in size, and receives groundwater and stormwater runoff from a stream channel north of the pond. The effluent from Unqua Pond is discharged from its southern boundary into Jones Creek, as shown in Figure 3.

Unqua was observed to support a medium-sized waterfowl population with respect to the size of the pond (approximately 17 per acre). Pekin ducks, mallards, Canadian geese and other species were obseved in total populations ranging from 50 to 200 and averaging 100 throughout the monitoring program.

Tackapausha Pond

The Tackapausha Pond is part of the Seaford Creek wetland system which lies entirely within the Tackapausha Nature Preserve. This 1.7-acre pond is located at the extreme southern end of the preserve and just north of Merrick Road. Seaford Creek itself consists of a single stream channel and two small ponds, one of which is Tackapausha Pond. The southward flowing stream originates south of Jerusalem Avenue and eventually discharges into a saltwater canal immediately south of Merrick Road, as shown in Figure 4. Except for commercial zones along most of the main roadways, residential areas are found adjacent to the preserve.

There are two influent locations to the Tackapausha Pond, the north influent and the south influent. Both influents are located along the main stream channel of Seaford Creek, but a divide in the stream between the two influents necessitates designation of both influent locations for sampling. The effluent stream for Tackapausha Pond is located at its southern end along Merrick Road.

The largest waterfowl population resided at Tackapausha. The number of waterfowl counted here ranged from 160 to over 500 with an average number of approximately 380. This would be equivalent to a density of 224 per acre.

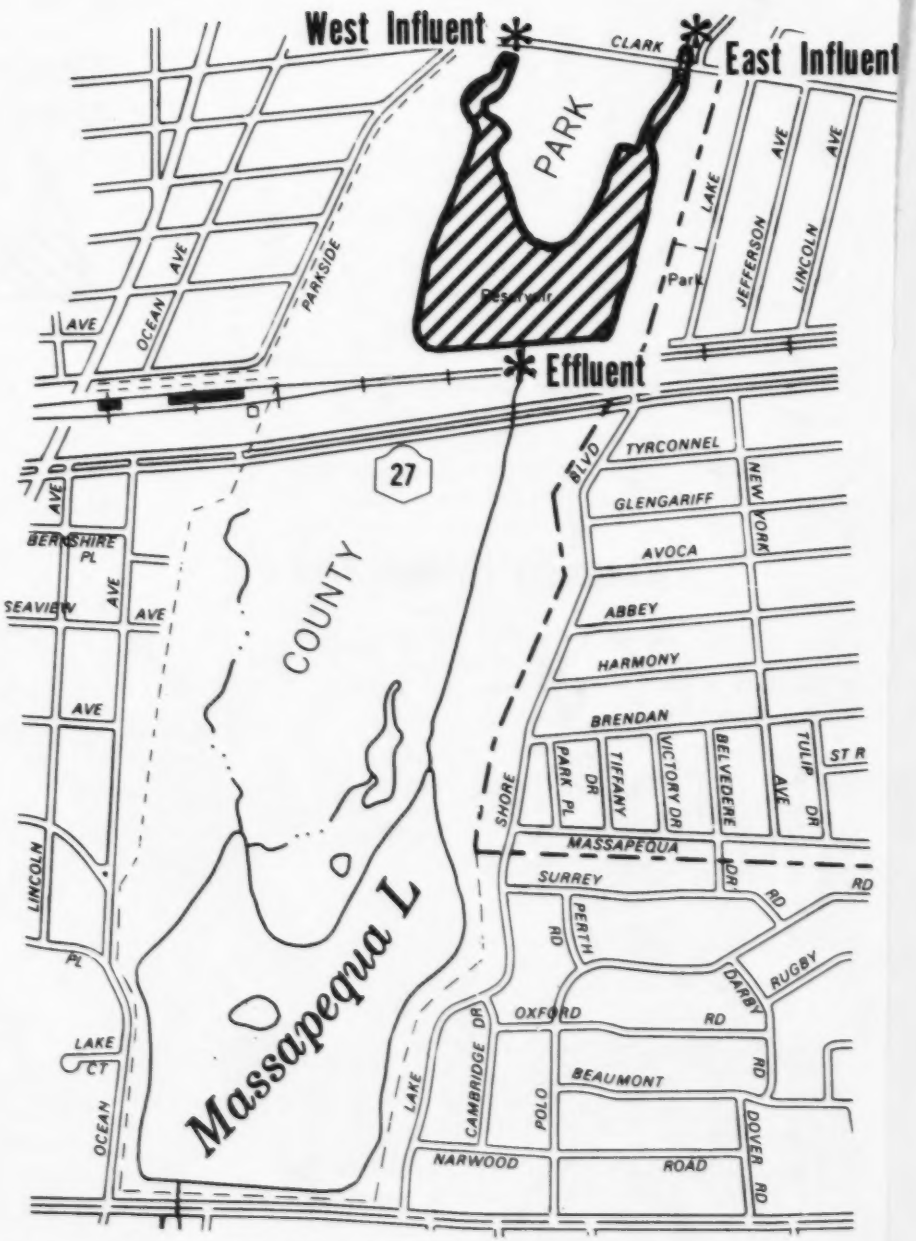


FIGURE 2 *Massapequa Reservoir study site*

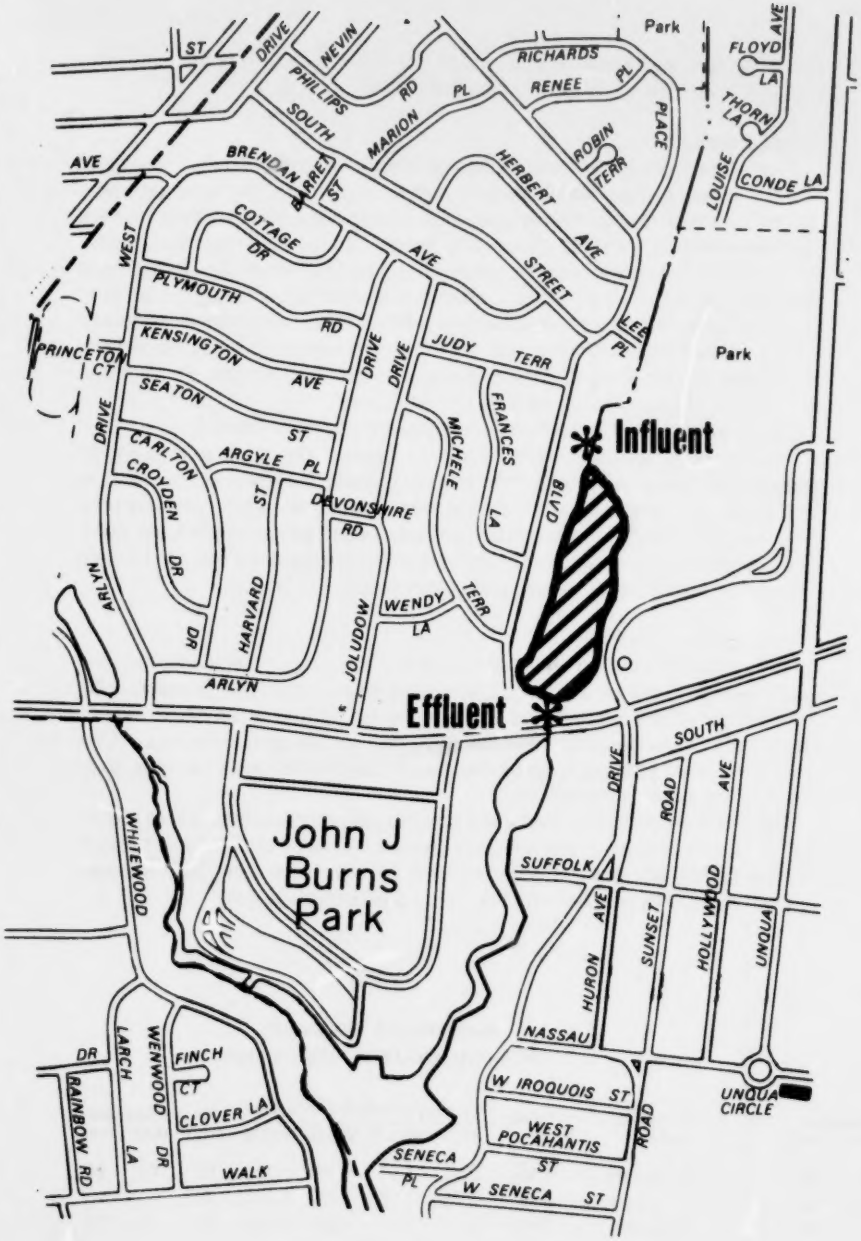


FIGURE 3 *Unqua Pond study site*

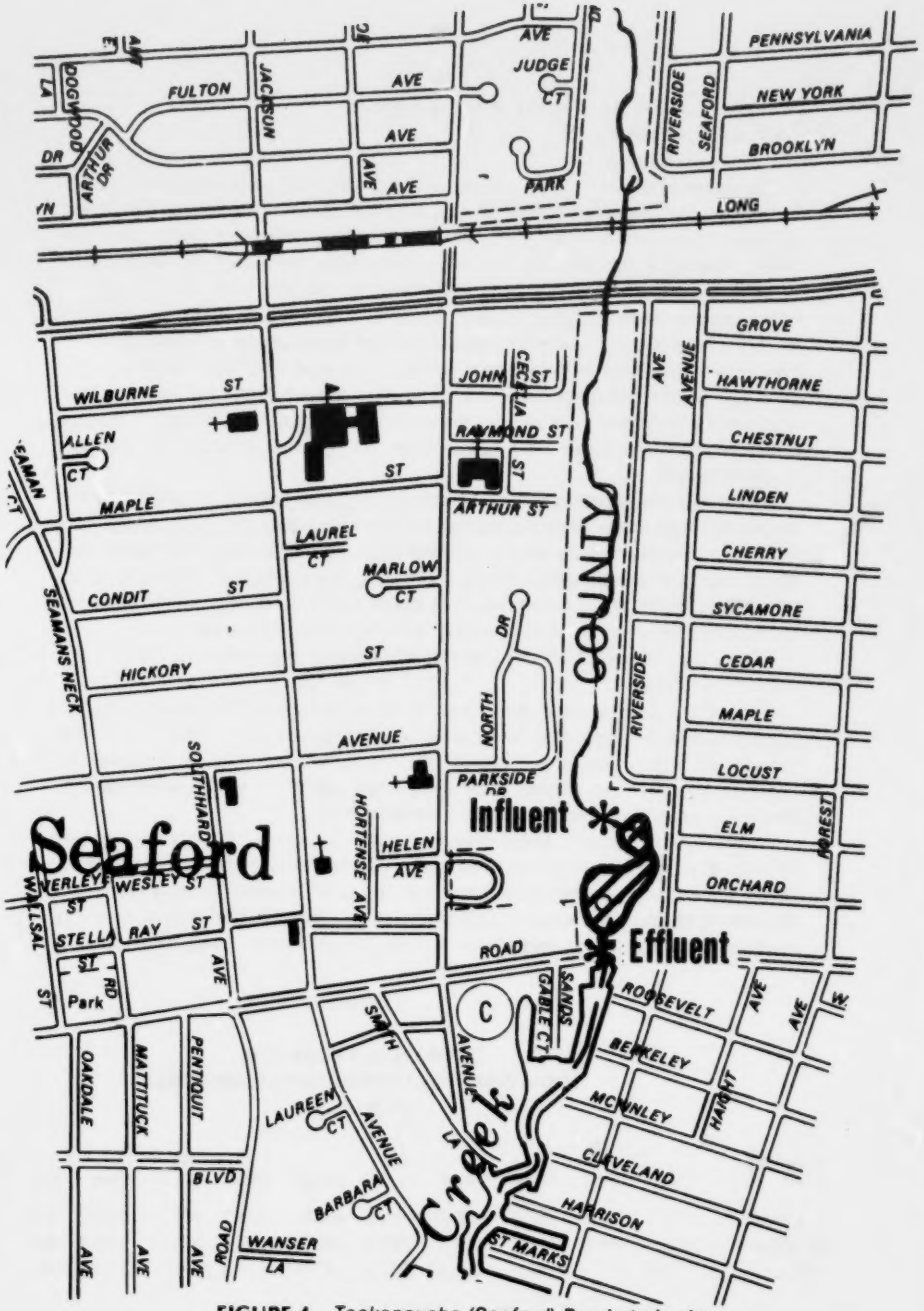


FIGURE 4 *Tackapausha (Seaford) Pond study site*

IV. ANALYSIS OF BACTERIAL AND CHEMICAL WATER SAMPLES

Massapequa Reservoir

The water analysis for coliform counts of the Massapequa Reservoir appear in Table 1. This data represents the log average coliform counts for the period of November 1979 to May 1980, when sampling occurred at least once per week. Averages for dry and wet days were also calculated to analyze the possible effect stormwater runoff may have on the reservoir.

As can be seen in Table 1, total, fecal and fecal strep average coliform counts of the influent samples largely exceed those of the effluent samples. The only exceptions are the east influent average total and fecal counts, sampled on the wet days. Samples taken from the west influent waters show much higher coliform counts than the east influent samples. Since the waters of the west influent were often found to be still, this may account for the high coliform levels.

Due to the small population of waterfowl (averaging about 25 birds) and the relatively large water area (16 acres), no adverse effect on the Massapequa Reservoir's water quality was expected from their activities. The lower coliform counts of the effluent waters, as opposed to the higher influent counts, tends to support this statement. The lower coliform counts in the effluent waters may also be due to the natural die-off of coliform bacteria in the pond.

The results of the chemical analysis of Massapequa Reservoir waters are depicted in Table 2.

Chemical analyses were performed to detect the concentration of nitrogen compounds in the reservoir. Nitrogen is an important nutrient essential for the growth of algae and other plants. Its concentration was determined to estimate whether the wastes originating from waterfowl in the Massapequa Reservoir have an adverse effect on water quality.

The results in Table 2 reveal that the concentration of total nitrogen at the effluent is within the same range as that entering the system from the east influent while 2 mg/L higher than that entering from the west. While it would be necessary to know the influent flow rate plus the quantity of nitrogen entering from other sources (e.g., underflow) in order to construct a mass balance, it is probably safe to conclude that waterfowl have a small impact upon the nitrogen levels based upon their numbers alone.

Unqua Pond

Table 3 contains the coliform sampling results for Unqua Pond. The data of Table 3 reveal higher overall effluent coliform counts for the total and fecal coliform tests. Strep counts are seen to be higher in the Pond's influent for the combined and dry samples. The higher overall coliform counts in the effluent of Unqua Pond suggest that the waterfowl population inhabiting Unqua Pond may have an effect on the pond's water quality. The higher coliform counts of samples collected on wet days indicate that coliform counts of samples collected on wet days indicates that coliforms are entering Unqua Pond from other sources, including the storm drainage system and possibly through bottom sediment scour during periods of high flows.

The results of the Unqua Pond sampling are shown in Table 4.

The chemical analysis results shown in Table 4 indicate a slightly higher nitrogen content in the Unqua Pond influent stream. The lower concentrations in the effluent stream would indicate that nitrogen is being removed from these waters, possibly being consumed by the algae and plant life in the pond. There seems to be no significant adverse effect on the pond's ecological environment due to the waterfowl population residing at Unqua.

Tackapausha Pond

The largest number of waterfowl observed throughout the monitoring program were at Tackapausha Pond. Their numbers averaged approximately 380. An analysis of the coliform data presented in Table 5 indicates a definite degradation of bacteriological water quality within this pond. Effluent coliform counts were found to be much higher than influent counts in all samples taken dry and wet weather conditions.

The chemical analyses conducted for nitrogen compounds revealed slightly higher concentrations in the influent stream for all tests except Total Kjeldahl Nitrogen (TKN) which was slightly higher in the effluent stream. Total Nitrogen is also slightly lower in the effluent. Table 6 lists these results.

Table 1

MASSAPEQUA RESERVOIR
LOG AVERAGE COLIFORM COUNTS (MPN/100 ml)
11/79 to 5/80

Sampling Point	Combined			Dry			Wet			No. of Samples		
	Total	Fecal	Strep	Total	Fecal	Strep	Total	Fecal	Strep	Dry	Wet	Total
E. Influent	1013.3	380.3	380.4	1005.2	495.3	412.8	1028.1	235.3	329.2	69	38	107
W. Influent	2835.6	965.6	766.7	3321.7	1378.4	596.1	2127.4	506.0	1195.1	69	38	107
Effluent	717.6	270.2	138.1	555.5	237.6	92.6	1134.8	340.1	276.5	69	38	107

Table 2

MASSAPEQUA RESERVOIR
CHEMICAL ANALYSIS RESULTS (mg/L)

Sampling Point	Total N	Average Levels 11/79 to 8/80				No. of Samples		
		TKN	NH3-N	N03-N	N02-N	Dry	Wet	Total
E. Influent	7.45	2.02	1.55	5.30	0.030	15	10	25
W. Influent	5.16	2.05	1.58	3.08	0.027	15	10	25
Effluent	7.13	2.14	1.57	4.96	0.029	15	10	25

Table 3

UNQUA POND
LOG AVERAGE COLIFORM COUNTS (MPN/100 ml)
11/79 to 5/80

Sampling Point	Combined Total	Combined Fecal	Combined Strep	Dry Total	Dry Fecal	Dry Strep	Wet Total	Wet Fecal	Wet Strep	No. of Samples Dry	No. of Samples Wet	No. of Samples Total
Influent	288.2	89.9	76.7	199.0	76.7	51.8	591.6	119.8	153.4	69	38	107
Effluent	474.4	211.4	73.3	283.0	128.0	28.8	1235.8	539.1	413.5	69	38	107

Table 4

UNQUA POND
CHEMICAL ANALYSIS RESULTS (mg/L)

Sampling Point	Total N	Average Levels 11/79 to 8/80 TKN	NH3-N	N03-N	N02-N	No. of Samples Dry	Wet	Total
Influent	7.18	2.79	2.11	4.36	0.035	15	10	25
Effluent	6.42	2.44	1.74	3.95	0.035	15	10	25

Table 5

TACKAPAUSHA POND
LOG AVERAGE COLIFORM COUNTS (MPN/100 ml)
11/79 to 5/80

Sampling Point	Combined Total	Combined Fecal	Combined Strep	Dry Total	Dry Fecal	Dry Strep	Wet Total	Wet Fecal	Wet Strep	No. of Samples Dry	No. of Samples Wet	No. of Samples Total
N. Influent	310.8	107.8	154.4	170.8	63.5	70.9	893.0	274.4	572.3	67	38	105
S. Influent	318.6	99.1	161.4	216.2	70.4	101.0	631.3	180.9	359.9	69	38	107
Effluent	3699	1781.0	1360.7	30000.0	1889.3	1345.2	5414.6	1600.0	1390.9	69	38	107

Table 6

TACKAPAUSHA POND
CHEMICAL ANALYSIS RESULTS (mg/L)

Sampling Point	Total N	Average Levels 11/79 to 5/80 TKN	NH3-N	N03-N	N02-N	No. of Samples Dry	Wet	Total
N. Influent	7.37	1.70	1.17	5.63	0.038	14	10	24
S. Influent	7.41	1.63	1.10	5.74	0.040	15	10	25
Effluent	6.60	1.80	1.13	4.77	0.031	15	10	25

The results in Table 6 seem to indicate that nitrogen, contained in the waterfowl discharges, is being consumed or deposited within the pond and is not being carried away in the effluent waters. The large quantity of fecal matter expected in the pond, due to the extremely large waterfowl population, would have been expected to result in higher effluent nitrogen compound concentrations if these compounds were not retained in the pond.

V. CONCLUSIONS

Among the three similar bodies of water monitored throughout this program, waterfowl activities seem to have the greatest effect upon the bacteriological quality of Tackapausha Pond. The extremely high coliform counts in Tackapausha's effluent stream, as compared to its influent stream, is one indication of the effect of the extremely large waterfowl density (averaging 224/acre) has on this pond's water quality.

The effect on pond water quality of smaller waterfowl densities is shown in the sampling results of Unqua Pond and the Massapequa Reservoir.

In the case of Unqua Pond, the difference between influent and effluent coliform counts shows some degradation of water quality. The waterfowl density here, averaging 17/acre, is suspected to be at least partially responsible for this degradation, but other factors such as animal fecal matter carried through the storm drain system on wet days (the sampling results for Unqua show higher coliform counts on wet days) and possible scour of bottom sediments during high flows may be the primary cause of water quality degradation in Unqua.

The sampling results of the Massapequa Reservoir show that the smallest waterfowl density observed in this monitoring program, averaging 1.6/acre, has little or no effect on the water quality of this body of water.

VI. RECOMMENDATIONS

The results of this monitoring program have provided an indication of the effect varying waterfowl densities can have on the bacteriological water quality of a pond or lake. Besides the effect on water quality, the activities of a large waterfowl population can also affect other factors in the wetland environment.

The presence of materials such as nitrogen, contained in the fecal matter of waterfowl, can aid the rapid growth of algae and other aquatic plants. It is recommended that sediment samples of the pond and lake bottoms be collected to assess and compare sediment composition for bacteria and nutrients such as nitrogen.

Another concern with the water quality of these three wetlands is the effect their effluents may have on water quality downstream. Public bathing beaches and open shellfishing waters may be adversely affected by contaminants traced to waterfowl activities in the wetlands upstream. Further studies should be conducted to determine if waterfowl upstream have an adverse effect on downstream receiving waters. If this is shown to be the case, measures may be required to limit numbers of waterfowl if downstream best uses of receiving waters are to be achieved and/or maintained.

REPORT ON WATERFOWL COUNT ON SOUTH SHORE OF NASSAU AND SUFFOLK COUNTIES

VII Introduction

Through the local Audubon Clubs, the New York State Department of Environmental Conservation, the Federation of NYS Bird Clubs, SUNY at Stony Brook and others, the LIRPB established contact with a number of people involved in birding on Long Island. Discussion revealed that actual counts on the particular freshwater ponds listed for the NURP Study were not available. However, the staff determined that by talking with knowledgeable people and by actually conducting a bird count, it would be possible to present a brief description of the waterbodies of interest and of their waterfowl populations.

In November of 1981 the LIRPB conducted a waterfowl count of the lakes and streams identified for further investigation. Section XI, *Waterfowl Count,* provides a brief description of each lake or pond, if notable; waterfowl species found and respective numbers; and date of field work.

The following people were involved in, and contributed greatly to, the waterfowl count:

1. Steven Dempsey — *Federation of New York State Bird Clubs*
2. William Lameroux — *President, Great South Bay Audubon Society*
3. Dr. Robert Smolker — *SUNY at Stony Brook, Department of Ecology* and Evolution, Professor of Ornithology
4. Dennis Puleston — *Naturalist and Lecturer in Ornithology*

VIII General Trends

Canada Geese and *Mallards* have increasingly become year-round residents and are now breeding on Long Island. The Canada Geese, particularly, frequent large open spaces, especially golf courses.

The Mallards have been gradually moving into the habitats of the *Black Duck* on Long Island. Some years ago, when Connetquot River State Park, was a private sportsman's club, mallards were specifically raised for hunting purposes. As a result, a Mallard population became well-established there once hunting was curtailed. NYSDEC has been concerned with the ever-decreasing numbers of Black Ducks and may undertake a study of this situation.

The Great South Bay and associated wetlands and streams have been a great source of food, but over the last 30-40 years the number of Bay ducks, especially the Greater Scaup, has been decreasing. The subsequent filling in of wetlands have had a direct and indirect effect on food resources.

It is believed that most waterfowl related pollution problems can be attributed to the semi-domestic species and the growing number of year-round residents that feed primarily on grasses and bread. Many of the migratory species such as the *Scaup, Canvasbacks and Mergansers* are fish eaters and contribute little to any high coliform counts. In addition to the domestic white ducks, birds such as the Mallards, Gadwalls, American Widgeons and Canadian Geese, consume large amounts of bread, and are probably the greatest contributors of coliform bacteria to the ponds.

The *Pekin* and other domestic ducks virtually do not move once they have been placed in ponds. Legislation to stop the practice of selling Easter ducks would be appropriate.

It has been suggested that the establishment of an educational program to discourage the feeding of bread and to promote its replacement with bird seed, which is more nutritious, could help decrease coliform counts. Since waterfowl are likely to consume smaller amounts of the more nutritious feed, the volume of feces produced and the associated coliform loading should be reduced accordingly.

IX List of Ponds Surveyed

Stream	Pond
a) *NASSAU COUNTY*	
Valley Stream	Valley Stream Pond
Macy Channel	Grant Park Pond
	Willow Pond
Pines Brook	Halls Pond
	Pines Pond
Mill River	Smith Pond
	South Pond
	Hempstead Lake
	Northwest Pond
	Northeast Pond
Parsonage Creek	Loft's Pond
	Swan Lake
Milburn Creek	Milburn Pond
East Meadow Brook	East Meadow Pond
	West Meadow Pond
	Smith Pond
	Mullener Pond
Cedar Swamp	Newbridge Pond
Bellmore Creek	Jones Pond
	Wantagh Pond
	Seaman Pond
Seaford Creek	Seaford Pond
Massapequa Creek	Massapequa Lake
	Massapequa Pond
	Massapequa Pond #1
	Massapequa Pond #2
	Massapequa Pond #3
Unqua Creek	Unqua Pond
b) *SUFFOLK COUNTY*	
Amityville Creek	Avon Lakes (3)
Woods Creek	Woods Lake
Santapogue Creek	Park Pond
Carlls River	Memorial Park Pond (Argyle Lake)
	Southards Pond
	Elda Lake
	Belmont Lake
Sampawams Creek	Hawleys Lake
	Guggenheim Lakes
Willets Creek	Lake Capri
Trues Creek	Trues Lake
Awixa Creek	Montfort Lake
Orowoc Creek	Pardee Ponds
	Orowoc Lake
Brightwater Canal	Cascade Lakes
Champlin Creek	Knapps Lake
	Duck's Lake
	Upper Winganhauppauge
	Lower Winganhauppauge
Westbrook Creek	Westbrook Pond
Connetquot River	Main Pond
	Hatchery Pond
Rattlesnake Brook	Slade Pond
	East Pond
Brown Creek	Mill Pond
	Lotus Lake
	San Souci Lakes
Tuthills Creek	West Lake
Patchogue River	Great Patchogue Lake
	Canaan Lake
Swan River	Swan Lake
Mud Creek	Robinson Pond
Hedge Creek	Dunton Lakes
Carmans River	Lower Lake
	Upper Lake

X Description of Species

A. *Grebes* — dive and pursue small aquatic animals. Nest in floating marsh vegetation.
Pied-Billed Grebe

B. *Swans* — dip head and neck into the water to feed on bottom vegetation. They also browse on shore grasses.
Mute Swan

C. *Geese* — they feed on grains, grass sprouts and some marine vegetation.
Canada Goose

D. *Surface-feeding Ducks* — Common ducks that dabble and tip in the shallows of fresh and salt water marshes. Although chiefly vegetarians, they eat some mollusks, insects and small fish.

Mallard	*European Widgeon*
Black Duck	*Shoveler*
Pintail	*Blue-Winged Teal*
Gadwall	*Green-Winged Teal*
Americal Widgeon	*Wood Duck*

E. *Bay Ducks* — commonly winter in coastal bays and river mouths. They eat more animal food than surface-feeding ducks.

Redhead	*Greater Scaup*
Canvasback	*Lesser Scaup*
Ring-Necked Duck	*Bufflehead*

F. Stiff-tailed Ducks — common on estuaries, lakes and rivers. In swimming the tail is often held up at a jaunty angle.
Ruddy Duck

G. Mergansers — are fish-eating diving ducks.
Common Merganser
Hooded Merganser — uncommon; found in wooded lakes and streams.

H. *Cranes and their Allies* — all are wading birds with long legs.
American Coot

I. Herons — most feed on aquatic animal life in shallow water.

Black-Crowned Night Heron	*Common Egret*
Great Blue Heron	*Snowy Egret*

XI Waterfowl Count

NASSAU COUNTY

11/21/81 1. Valley Stream

A. *Valley Stream Pond* — fairly dried up and reduced in size.

16 Mallard	50 Gulls — various species

11/21/81 2. Macy Channel

A. *Grant Park Pond* —becoming quite polluted

100 Canada Geese	1 Shoveler
20 Mallard	6 Canvasback
200 Black Duck	40 Greater Scaup
4 Pintail	10 Hooded Merganser
25 American Widgeon	

B. *Willow Pond*

1 Mute Swan	1 Europen Widgeon
32 Canada Geese	1 Bufflehead
61 Mallard	17 Hooded Merganser
300 Black Duck	5 Coot
2 Gadwall	3 Pekin Duck
25 American Widgeon	

11/21/81 3. Pines Brook

A. *Halls Pond*

30 Canada Geese	4 Pekin Duck
45 Mallard	40 Ring-Billed Gulls
1 Black Duck	

B. *Pines Pond* — has either completely dried up or been filled in.

11/21/81 4. Mill River

A. *Smith Pond*

3 Mallard	10 Green-Winged Teal
250 Black Duck	27 Canvasback
4 American Widgeon	8 Hooded Merganser
4 Shoveler	

B. *South Pond*

16 Mallard	60 Gulls - various species

C. *Hempstead Lake* — the largest fresh water body in Nassau, but noticeably drying up. Probably partially due to excessively dry conditions.

160 Canada Geese	40 Green-Winged Teal
30 Mallard	12 Great Scaup
400 Black Duck	1 Common Merganser
15 Pintail	12 Hooded Merganser
6 American Widgeon	100 Gulls - various species

D. *Northwest Pond* — completely dried up.

XI Waterfowl Count (continued)

E. *Northeast Pond* — it was noted that there were many snapping turtles and therefore Mallards cannot survive here.
1 Black-Crowned Night Heron

11/11/81 5. Parsonage Creek

A. *Loft's Pond* — small pond with a high density of waterfowl.

50 Canada Geese	30 American Widgeon
40 Mallard	2 Pekin Duck
250 Black Duck	

B. *Swan Lake* — not included in list; it usually has a high density of waterfowl.

60 Canada Geese	13 Pekin Duck
60 Mallard	50 Gulls - various species
200 Black Duck	

11/11/81 6. Milburn Creek

A. *Milburn Pond* — has the highest density and diversity of all ponds in Nassau.

1 Mute Swan	25 American Widgeon
30 Canada Geese	10 Lesser Scaup
120 Mallard	6 Coot
400 Black Duck	10 Pekin Duck
12 Gadwall	

Also usually at the lake at this time: Redheads, Green-Winged Teal and Pintail.

11/11/81 7. East Meadow Brook

A. *East Meadow Pond* — moderately flowing pond.

1 Black Duck	15 Hooded Merganser

B. *West Meadow Pond* — stagnant flow.

6 Mallard	4 Hooded Merganser

C. *Smith Pond*

15 Mallard	6 Green-Winged Teal
15 Black Duck	10 Hooded Merganser
4 Gadwall	

D. *Mullener Pond*

15 Mallard	2 Hooded Merganser
15 Green-Winged Teal	

11/11/81 8. Cedar Swamp

A. *Newbridge Pond* — abuts railroad tracks.

6 Canada Geese	1 Wood Duck
80 Mallard	6 Hooded Merganser
40 Black Duck	7 Pekin Duck
6 American Widgeon	5 Gulls - various species

11/11/81 9. Bellmore Creek

A. *Jones Pond* (in Mill Pond Park) — moderate-sized pond with a few small islands.

5 Mute Swan	10 Hooded Merganser
100 Mallard	70 Coot
600 Black Duck	300 Gulls - various species
10 Gadwall	

B. *Wantagh Pond* — good flow rate; many lilies still on pond.

1 Pied-Billed Grebe	50 Hooded Merganser
6 Mallard	1 Coot
20 Black Duck	2 Pekin Duck
7 Redhead	50 Gulls - various species
1 Lesser Scaup	

C. *Seaman Pond*

1 Pied-Billed Grebe	7 Ruddy Duck
4 Black Duck	3 Coot
6 Ring-Necked Duck	

11/11/81 10. Seaford Creek

A. *Seaford Pond* — good flow rate; small pond located in a park.

50 Mallard	4 Pekin Duck
25 Black Duck	1 Domestic Goose
8 American Widgeon	25 Gulls - various species

11/11/81 11. Massapequa Creek

A. *Massapequa Lake* — large area, with an island in center.

2 Mute Swan	1 Canvasback
20 Mallard	12 Coot
100 Black Duck	70 Ring-Billed Gull

B. *Massapequa Pond* (Reservoir)

30 Mallard	1 Coot
4 Hooded Merganser	1 Greater Black-Backed Gull

C. *Massapequa Pond #1-2-3* — were not checked. It was felt that they were small, insignificant ponds as far as waterfowl were concerned. It was assumed that a few Mallards and Black Duck would be found.

11/11/81 12. Unqua Creek

A. *Unqua Pond* — very slow moving; abuts park on east side.

125 Canada Geese	30 American Widgeon
60 Mallard	100 Hooded Merganser
200 Black Duck	20 Gulls - various species

XI Waterfowl Count (continued)

SUFFOLK COUNTY

11/29/81 1. Amityville Creek

A. *Avon Lakes (1)* — small in size with debris on edges.

3 Mallard	8 American Widgeon
250 Black Duck	6 Hooded Merganser
2 Gadwall	

B. *Avon Lakes (2)* — surrounded by residential area.

50 Canada Geese	31 Canvasback
200 Mallard	20 Hooded Merganser
350 Black Duck	6 Ring-Billed Gull

C. *Avon Lakes (3)* — small pond in park; noticeably rusty water.

75 Mallard	100 American Widgeon
10 Gadwall	60 Gulls - various species.

11/29/81 2. Woods Creek

A. *Woods Lake* — notiecable odor — possible sewage problem from residential area on east side?

6 Mallard	1 Ring-Billed Gull
10 Black Duck	

11/30/81 3. Santapogue Creek

A. *Park Pond* —small in size with numerous articles of junk within and on the sides.

2 Mallard

11/29/81 4. Carlls River

A. *Memorial Park Pond* (Argyle) — a large sized pond in park, with a large diversity and density of waterfowl. Very good for wintering waterfowl.

13 Mute Swan	38 Lesser Scaup
220 Canada Geese	10 Hooded Merganser
90 Mallard	20 Coot
280 Black Duck	1 Exotic-Egyptian Goose
2 Pintail	300 Gulls - various species
15 Canvasback	

11/30/81 B. *Southards Pond* — fairly large-sized pond with a lot of decaying matter. Not a lot in numbers but an important wetland area in migration route.

5 Mute Swan	80 Gadwall
1 Canada Goose	12 Hooded Merganser
2 Mallard	8 Coot
8 Black Duck	420 Gulls - various species

11/30/81 C. *Elda Lake*

118 Canada Geese	17 Ruddy Duck
12 Mallard	2 Hooded Merganser
17 Black Duck	15 Pekin Duck
25 American Widgeon	300 Gulls - various species

11/30/81 D. *Belmont Lake* — large-sized with a large waterfowl population. Excellent area for wintering waterfowl, including a resident wood duck.

1 Pied-Billed Grebe	15 Redhead
7 Mute Swan	37 Ruddy Duck
260 Canada Geese	53 Coot
152 Mallard	13 Pekin Duck
10 Black Duck	2 Pekin and Mallard Hybrid
29 Gadwall	2 Muscovy Duck
2 Shoveler	260 Gulls - various species

11/29/81 5. Sampawams Creek

A. *Hawleys Lake* — many small streams, but area is mostly filled wetlands revegetated by phragmites and low woods with garbage strewn about.

12 Mallard

11/30/81 B. *Guggenheim Lakes* — never many waterfowl found here.

2 Mute Swan	275 Gulls - various species

11/29/81 6. Willets Creek

A. *Lake Capri*

25 Canada Geese	37 Lesser Scaup
3 Mallard	4 Hooded Merganser
120 Black Duck	1 Pekin Duck
8 American Widgeon	1 Exotic-Egyptian Duck
3 Redhead	10 Gulls - various species
6 Canvasback	

2 field visits

11/26/81 7. Trues Creek

11/29/81 A. *Trues Lake* — small sized pond with a good number of waterfowl. It has become eutrophic.

	1st visit	2nd visit
Mallard	3	0
Black	175	131
Gadwall	1	0

XI Waterfowl Count (continued)

2 field visits:

11/26/81 8. Brightwater Canal

A. *Cascade Lakes (5)*

	1st visit	2nd visit
Pied-Billed Grebe	0	1
Mute Swan	1	1
Canada Geese	15	97
Mallard	39	0
Black Duck	60	0
Hooded Merganser	12	7
Ring-Billed Gull	25	22

11/26/81 9. Awixa Creek

A. *Montfort Lake* — inaccessible

11/26/81 10. Orowoc Creek

A. *Pardee Pond* — adjacent to high school. Tends toward eutrophic and stagnating conditions in summer, due to lily overgrowth.

3 Canada Geese
23 Mallard
4 Gadwall
6 Hooded Merganser
2 Ring-Billed Gull

B. *Orowoc Lake* — near McDonalds. It used to be an excellent bird spot. Now its condition is very poor. Water was mucky with debris scattered about.

3 Mute Swan
30 Mallard
3 Gadwall
1 Canvasback
4 Coot
1 Pekin Duck
2 Muscovy Duck
57 Gulls - various species

11/26/81 11. Champlin Creek

A. *Knapps Lake* — usually sustains a good winter population of Grebes and Coots and is considered the best siting for Wood Ducks.

6 Mute Swan
5 Mallard
10 Gadwall
12 Hooded Merganser
42 Gulls - various species

B. *Duck's Lake*

39 Mallard
8 Gadwall

C. *Upper Winganhauppauge* — a good wintering duck pond.

12 Mallard
1 Black Duck
8 American Widgeon
3 Shoveler
15 Canvasback
6 Hooded Merganser
1 Ring-Billed Gull

D. *Lower Winganhauppauge* — inaccesible

11/29/81 12. Westbrook Creek

A. *Westbrook Pond* — always few waterfowl for its size.

21 Mallard
4 Black Duck
16 Gadwall
4 American Widgeon

11/29/81 13. Connetquot River

A. *Main Pond* — maintains a good collection of wintering duck. Only place in Suffolk where a Common Merganser was sited. It has a resident Wood Duck population of 4 and a resident Osprey population. Herons can be found in the summer along mouth of river.

2 Pied-Billed Grebe
6 Mute Swan
52 Canada Geese
25 Mallard
71 Gadwall
160 American Widgeon
120 Canvasback
6 Ring-Necked Duck
21 Lesser Scaup
15 Bufflehead
13 Coot
10 Gulls - various species

B. *Hatchery Pond* — not usually a large waterfowl population; further inland than Main Pond.

4 Black Duck
10 Gadwall
11 Lesser Scaup

11/29/81 14. Rattlesnake Brook

A. *Slade Pond* — nothing - small in size; sheltered.

B. *East Pond* — small in size; sheltered.

2 Mute Swan
1 Herring Gull

Green Creek, and, its connected pond directly north of Montauk Highway and west of Mill Pond on Brown Creek, has a good number of migratory species including Hooded Mergansers. It was felt that this river system should also be included in this project study.

11/29/81 15. Brown Creek

A. *Mill Pond* — most prolific and excellent wintering duck area and a good site for Ring-Necked Ducks.

2 Mute Swan
86 Mallard
30 Gadwall
2 American Widgeon
2 Shoveler
1 Canvasback
4 Ring-Necked Duck
4 Coot
10 Pekin Duck
3 Muscovy
65 Ring-Billed Gull

B. *Lotus Lake* — not a very populated lake.

1 Mallard
3 Gadwall
6 American Widgeon
4 Canvasback

C. *Sans Souci Lake* — nothing. Has never had a significant wintering waterfowl population. Devoid of life; clear bottom.

XI Waterfowl Count (continued)

11/22/81 16. Tuthills Creek

A. *West Lake*

4 Pied-Billed Grebe	14 Ring-Necked Duck
2 Mute Swan	2 Coot
8 Mallard	134 Gulls - various species
28 American Widgeon	

11/22/81 17. Patchogue River

A. *Great Patchogue Lake* — excellent duck wintering area.

5 Pied-Billed Grebe	8 Canvasback
7 Mute Swan	1 Ring-Necked Duck
4 Canada Geese	7 Lesser Scaup
18 Mallard	26 Ruddy Duck
3 Pintail	1 Hooded Merganser
37 Gadwall	81 Coot
4 American Widgeon	14 Pekin Duck
9 Shoveler	128 Gulls - various species
2 Green-Winged Teal	

B. *Canaan Lake* — not very important as a residence for waterfowl. Some trash scattered about.

6 Pied-Billed Grebe	1 Green-Winged Teal
2 Mute Swan	18 Ring-Necked Duck
34 Mallard	34 Coot
2 Gadwall	8 Pekin Duck
39 American Widgeon	1 Muscovy
4 Shoveler	68 Gulls - various species

11/14/81 18. Swan River

A. *Swan Lake* — good wintering duck population with a nesting Pied-Billed Grebe.

2 Pied-Billed Grebe	1 Redhead
2 Mute Swan	1 Canvasback
1 Canada Goose	1 Ring-Necked Duck
24 Mallard	6 Lesser Scaup
2 Black Duck	37 Coot
72 Gadwall	2 Pekin Duck
169 American Widgeon	8 Gulls - various species

11/14/81 19. Mud Creek

A. *Robinson Pond*

21 Canada Geese	6 Green-Winged Teal
70 Mallard	14 Pekin Duck
1 Black Duck	1 Muscovy
11 Pintail	5 Exotic-Egyptian Geese
32 American Widgeon	388 Gulls - various species

11/14/81 20. Hedge Creek

A. *Dunton Lakes*

2 Mute Swan	24 Mallard
46 Canada Geese	2 Herring Gull

11/14/81 21. *Carmans River*—the mouth of the river, near the Great South Bay, is noted for large wintering waterfowl populations, although it is becoming eutrophic. In the winter a whistling swan population can be seen.

A. *Lower Lake*

2 Mute Swan	16 American Widgeon
17 Canada Geese	2 Herring Gull
5 Mallard	

B. *Upper Lake*

6 Mute Swan	2 Ring-Billed Gull
32 Canada Geese	

Carmans River Bird Count

The following data is an extensive list of birds that have been identified along the Carmens River and its banks by Dennis Puleston.

To the right of each checked bird you will find the following symbols:

U for upper river, that is, anywhere north of Montauk Highway.
L for lower river, anywhere south of the Montauk Highway, all the way to the mouth of the river at Long Point.
W for winter, that is, only found regularly during the fall and winter months.
R for rare, meaning seen only once or so every few years.
B for breeding, at least one breeding record.

Therefore, those marked only **U**, **L** or **UL** can be assumed to be transients, that is, species passing through the area on spring and fall migrations

Teal, Green-winged	UL
Teal, Blue-winged	UL
Widgeon, European	URW
Widgeon, American	ULW
Shoveler	URW
Duck, Wood	UB
Redhead	UW
Duck, Ring-necked	UW
Canvasback	UW
Scaup, Greater	LW
Scaup, Lesser	UW
Goldeneye, Common	LW
Bufflehead	ULW
Duck, Ruddy	ULW
Merganser, Hooded	ULW
Merganser, Common	ULW
Merganser, Red-breasted	LW
Goshawk	ULWR
Hawk, Sharp-shinned	UW
Hawk, Cooper's	UWR
Hawk, Red-tailed	ULB
Hawk, Red-shouldered	UR
Hawk, Broad-winged	ULB
Hawk, Rough-legged	LW
Eagle, Bald	LWR
Hawk, Marsh	LB
Osprey	ULB
Falcon, Peregrine	LWR
Hawk, Pigeon	ULWR
Hawk, Sparrow	ULB
Grouse, Reffed	ULB
Bobwhite	ULB
Pheasant, Ring-necked	ULB
Rail, King	LWR
Rail, Virginia	ULB
Sora	ULR
Gallinule, Common	ULW
Coot, American	ULW
Killdeer	ULB
Plover, Amer. Golden	ULW
Plover, Black-bellied	ULW
Turnstone, Ruddy	ULW
Woodcock, American	ULB
Snipe, Common	UL
Sandpiper, Spotted	ULB
Yellowlegs, Greater	UL
Yellowlegs, Lesser	UL
Sandpiper, Pectoral	LR
Sandpiper, Least	UL
Gull, Great Bl.-backed	UL
Gull, Herring	UL
Gull, Ring-billed	UL
Tern, Common	L
Tern, Least	L
Tern, Black	LR
Dove, Rock	ULB
Dove, Mourning	ULB
Cuckoo, Yellow-billed	ULB
Cuckoo, Black-billed	ULB
Owl, Barn	ULB
Owl, Screech	ULB
Owl, Great Horned	ULB
Owl, Snowy	LWR
Loon, Common	ULW
Loon, Red-throated	LWR
Grebe, Horned	LW
Grebe, Pied-billed	UL
Cormorant, Double-cr.	L
Heron, Great Blue	UL
Heron, Green	ULB
Heron, Little Blue	UR
Egret, Cattle	L
Egret, Common	UL
Egret, Snowy	UL
Heron, Black-cr. N	UL
Bittern, Least	UL
Bittern, American	L
Ibis, Glossy	ULR
Swan, Mute	ULB
Goose, Canada	ULB
Mallard	ULB
Duck, Black	ULB
Gadwall	UL
Pintail	UL

Owl, Long-eared	ULR
Owl, Short-eared	ULR
Owl, Saw-whet	ULWR
Whip-poor-will	ULB
Nighthawk, Common	UL
Swift, Chimney	ULB
Hummingbird, Ruby-th.	ULB
Kingfisher, Belted	UL
Flicker	ULB
Woodpecker, Red-bel.	ULB
Sapsucker, Yellow-bel.	UL
Woodpecker, Hairy	ULB
Woodpecker, Downy	ULB
Kingbird, Eastern	ULB
Flycatcher, Great C'd	ULB
Phoebe, Eastern	ULB
Flycatcher, Yellow-b'd	UL
Flycatcher, Traill's	UL
Flycatcher, Least	ULB
Pewee, Eastern Wood	ULB
Flycatcher, Olive-sided	UL
Swallow, Tree	ULB
Swallow, Rough-winged	ULB
Swallow, Barn	ULB
Martin, Purple	ULB
Jay, Blue	ULB
Crow, Common	ULB
Crow, Fish	ULB
Chickadee, Black-capped	ULB
Titmouse, Tufted	ULB
Nuthatch, White-br'd	ULB
Nuthatch, Red-breasted	ULW
Creeper, Brown	ULB
Wren, House	ULB
Wren, Winter	ULW
Wren, Carolina	ULB
Wren, Long-billed Msh	LB
Mockingbird	ULB
Catbird	ULB
Thrasher, Brown	ULB
Robin	ULB
Thrush, Wood	ULB
Thrush, Hermit	UL
Thrush, Swainson's	UL
Thrush, Gray-cheeked	UL
Veery	ULB
Bluebird, Eastern	ULB
Gnatcatcher, Blue-gray	UL
Kinglet, Golden-crowned	UL
Kinglet, Ruby-crowned	UL
Waxwing, Cedar	UL
Starling	ULB
Vireo, White-eyed	ULB
Vireo, Yellow-throated	ULB
Vireo, Solitary	UL
Vireo, Red-eyed	ULB
Warbler, Black-and-Wh.	ULB
Warbler, Prothonotary	UR
Warbler, Worm-eating	UR
Warbler, Blue-winged	ULB
Warbler, Tennessee	UL
Warbler, Orange-cr'd	ULR
Warbler, Nashville	UL
Warbler, Parula	UL
Warbler, Yellow	ULB
Warbler, Magnolia	UL
Warbler, Cape May	UL
Warbler, Black-th'd Bl.	UL
Warbler, Myrtle	UL
Warbler, Black-th'd Gr'n	UL
Warbler, Cerulean	ULR
Warbler, Blackburnian	UL
Warbler, Chestnut-sided	ULB
Warbler, Bay-breasted	UL
Warbler, Black-poll	UL
Warbler, Pine	ULB
Warbler, Prairie	ULB
Warbler, Palm	UL
Ovenbird	ULB
Waterthrush, Northern	UL
Warbler, Kentucky	ULR
Warbler, Connecticut	ULR
Warbler, Mourning	ULR
Yellowthroat	ULB
Chat, Yellow-breasted	ULR
Warbler, Hooded	ULR
Warbler, Wilson's	UL
Warbler, Canada	ULB
Redstart, American	ULB
Sparrow, House	ULB
Bobolink	UL
Meadowlark, Eastern	ULB
Blackbird, Redwinged	ULB
Oriole, Orchard	ULBR
Oriole, Baltimore	ULB
Blackbird, Rusty	ULW
Grackle, Common	ULB
Cowbird, Brown-headed	ULB
Tanager, Scarlet	ULB
Cardinal	ULB
Grosbeak, Rose-br.	ULB
Bunting, Indigo	ULB
Grosbeak, Evening	ULW
Finch, Purple	ULB
Finch, House	ULB
Redpoll, Common	ULW
Siskin, Pine	ULW
Goldfinch, American	ULB
Towhee, Rufous-sided	ULB
Sparrow, Savannah	ULW
Sparrow, Sharp-tailed	LB
Sparrow, Seaside	LB
Junco, Slate-colored	ULW
Sparrow, Tree	ULW
Sparrow, Chipping	ULB
Sparrow, Field	ULB
Sparrow, White-crowned	ULW
Sparrow, White-thr'd	ULW
Sparrow, Fox	ULW
Sparrow, Lincoln's	ULW
Sparrow, Swamp	ULB
Sparrow, Song	ULB
Bunting, Snow	ULW

Appendix F

Stormwater Runoff Modeling on the South Shore of Long Island

Lawler, Matusky and Skelly Engineers
and Fanning and Phillips

Final Draft Report to the Long Island Regional Planning Board, June 1982, Appendix C

CHAPTER C-1.0

INTRODUCTION

One of the tasks of the consultant in the Long Island National Urban Runoff Program (NURP) is to determine what reduction in coliform loadings to the bays is needed to reopen uncertified shellfish areas. New York State regulations allow commercial shellfishing only in Class SA waters, and the median Most Probable Number (MPN) value in any series of water samples taken from the shellfish area must be less than 70 per 100 ml. Previous studies (Tetra Tech 1977a; Weston 1977) have shown that one of the major reasons that any shellfish bed is closed on long Island is the bacterial load contributed by stormwater runoff reaching the bays through existing stream channels and direct overland runoff. Various measures to reduce this load are being evaluated, but the question is how much load reduction is required to reopen beds.

Various models (Tetra Tech 1977b; HydroQual 1981) have been developed to predict the hydrodynamics and water quality of the area, most notably the coarse-grid model developed in the Long Island 208 study. These models are fairly expensive and cumbersome to run for any long-term analysis. Because of the linearity of the mathematical equations that describe the system, however, a simpler model can be developed that can be run for extended periods of time and produce a statistical analysis of the coliform concentrations in the bays. Basically, the 208 quality model is run separately for each of the point sources and boundary conditions; the effect of a number of discharges on a given location is the sum of their individual effects. These effects can be ratioed up or down depending on the magnitude of each discharge. By incorporating each effect into a computer program and using various statistical routines to generate and analyze data, a mathematical model can be developed to assess the long-term effects of control measures on the bay system.

A long-term analysis of coliform levels is required because the New York State Department of Environmental Conservation (NYSDEC) requires a substantial data base before reevaluating shellfish bed closure (Redman 1981). With this as the focal point, a model was developed that combines existing models with statistics and empirical data.

The format of this Appendix is as follows. Chapter C-2.0 describes the use of the existing hydrodynamic and water quality models. The development of the Matrix Manipulation Model (MMM) is given in Chapter C-3.0. The model is compared with long-term data in Chapter C-4.0, and Chapter C-5.0 presents the storm load reductions needed to reopen shellfish beds.

CHAPTER C-2.0

USE OF THE SOUTH SHORE AND GREAT SOUTH BAYS 208 MODELS

2.1 INTRODUCTION

The documentation, user's guide, calibration, and verification of the 208 models can be found in the 208 report references (Tetra Tech 1977a,b, 1978). The hydrodynamic model uses the equations of continuity and motion to determine real-time flows and tidal elevations, which are used by the quality model to determine water quality by conservation of mass. The bays are divided into finite control volumes, or nodes, that are connected by channels, through which internodal transport occurs. Water quality concentrations are computed for each node. The system representation is shown in Figure C-2.0-1.

2.2 HYDRODYNAMIC MODEL

The hydrodynamic model was set up and run for average summer conditions (Tetra Tech 1977a). Mean tides were used for the four inlets (East Rockaway, Jones, Fire Island, and Moriches), and a summer evaporation rate of 4 in. per month was set for all areas. Summer baseflows were used for the streams (Table C-2.0-1), and historical average flows were input for the other point sources (Table C-2.0-2). The model was run until it reached a quasi steady-state condition (repeating tidal hydraulics). The real-time flows were then averaged over a tidal cycle to produce tidally averaged flows for input to the quality model.

There are two primary reasons why tidally averaged rather than real-time flows were used. First, the quality model would give different results, depending on whether storm runoff occurred at high tide or low tide. This would create an infinite number of storm/tide combinations to be looked at. Second, the final purpose of the modeling effort must be kept in mind: to generate long-term coliform concentrations in the bays as a result of rainfall events. If a long period of record is taken (say a year), the tidal stages and storms would cancel out. There would be roughly the same number of storms occurring at high tide as at low tide. Therefore, it was decided to use tidally averaged flows in the quality model.

Table C-2.0-1

STREAM CHARACTERISTICS USED IN THE HYDRODYNAMIC AND WATER QUALITY MODELS

Stream	Node	Summer Baseflow (cfs)	Total Coliform Background Concentration (MPN/100 ml)	Total Coliform[a] Storm Event Load (10 − ± MPN)
Mill River	11	6.0	8160	500.0
Seamans Creek	17	2.2	1000	83.5
Seaford Creek	17	1.9	1000	58 9
Parsonage Creek	18	1.8	4000	247.0
Milburn Creek	19	6.5	2480	118.0
East Meadow Brook	21	12.7	690	399.0
Cedar Swamp Creek	23	6.4	1890	125.0
Newbridge Creek	23	.8	1000	34.6
Bellmore Creek	40	8.3	1070	217.0
Massapequa Creek	41	9.1	910	312.0
Unqua River	51	.1	500	117.0
Carman Creek	51	3.2	3980	124.0
Amityville Creek	52	2.7	970	47.8
Woods Creek	52	.2	500	31.7
Howell Creek	52	.1	500	10.0
Great Neck Creek	53	1.9	24000	30.5
Strongs Creek	53	1.5	3350	38.2
Neguntatogue Creek	53	2.9	88700	38.8
Little Neck Creek	53	.1	500	25.2
Santapogue Creek	54	3.4	12250	219.0
West Babylon Creek	54	.1	500	44.2
Carlls River	54	25.8	4150	340.0
Sampawams Creek	55	9.2	2620	143.0
Willets Creek	55	1.9	3300	74.6
Skookwams Creek	55	.8	4300	19.2
Trues Creek	56	1.4	4300	37.5
Penataquit Creek	76	4.7	27650	40.2
Watchogue Creek	76	2.8	27650	13.0
Orowoc Creek	76	2.0	9550	195.0
Awixa Creek	76	1.5	35000	35.0
Cascade Lakes	76	1.9	10000	27.9
Lawrence Creek	76	4.7	10000	24.3
Champlin Creek	77	5.5	6600	122.0
Connetquot River	79	39.6	510	36.1
Green Creek	82	3.4	480	36.0
Brown Creek	82	6.2	260	39.7
Tuthills Creek	84	4.7	15	21.8
Patchogue River	84	15.9	9650	85.3
Swan River	84	9.8	9300	29.7
Mud Creek	85	4.1	8650	.8
Abets Creek	85	.1	500	1.0
Hedges Creek	85	.7	500	.7
Beaverdam Creek	87	1.2	500	2.2
Motts Brook	87	1.4	500	.9
Carmans River	89	18.1	430	.1

[a]Based on 2-in. in 12-hr rainfall.

NOTE: Overland (non-stream) runoff loads are based on 6.2 × 10^{10} MPN/acre/inch of rain

Table C-2.0-2

POINT SOURCES

Name	Node	Historical Average	
		Flow (cfs)	Total Coliform (MPN/100 ml)
West Long Beach STP	2	1.1	450
Lawrence STP	2	1.6	1000
Oceanside Incinerator	9	3.1	10220
Bay Park STP	13	104.4	520
Long Beach STP	13	11.3	260
Merrick Incinerator	22	1.3	10390
Jones Beach STP	34	0.3	140
Ocean Beach STP	68	0.3	2200
Patchogue STP	84	0.5	5960
LILCO	14	-400.0 (withdrawal)	—
LILCO	9	400.0	—

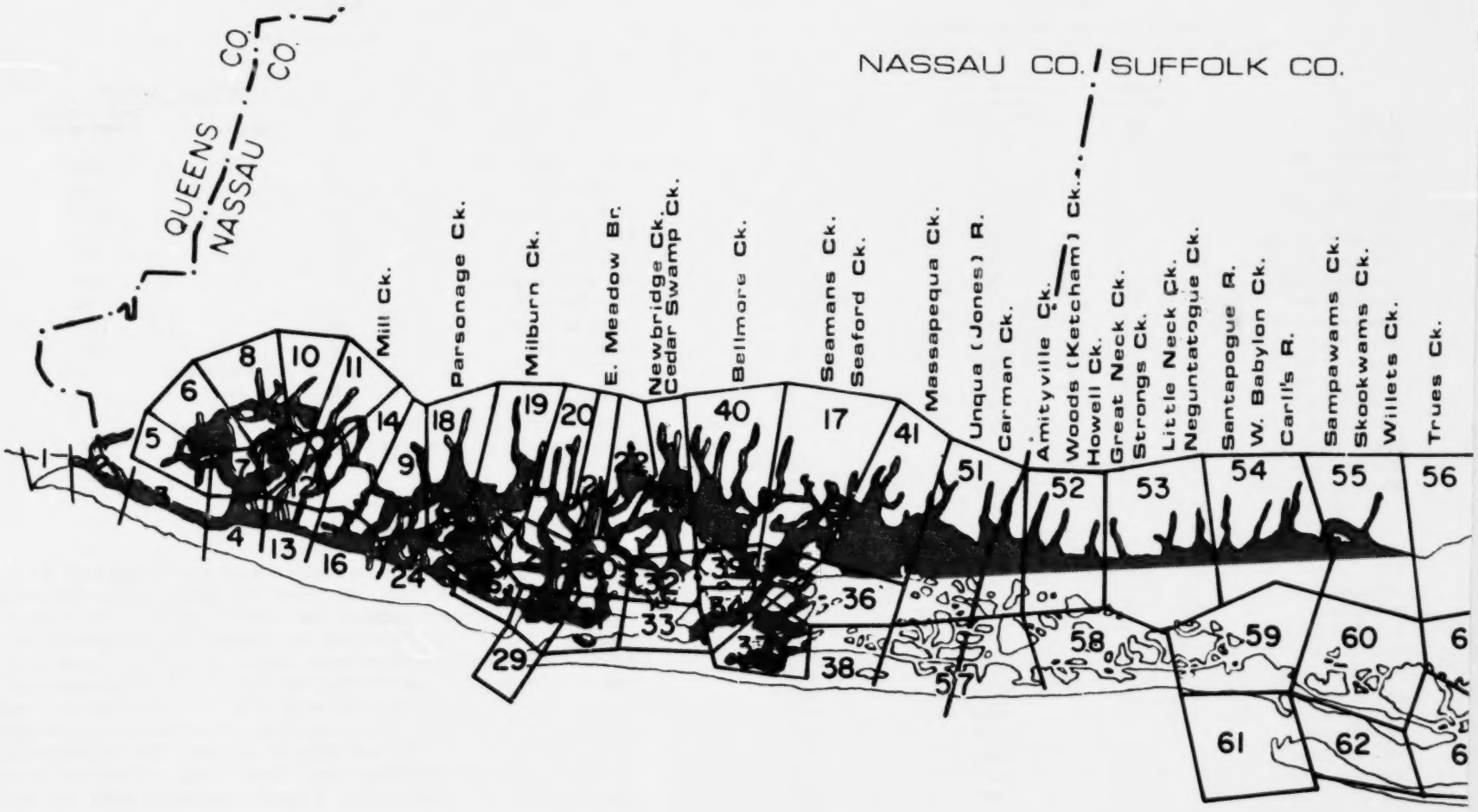
Source: Tetra Tech 1977a

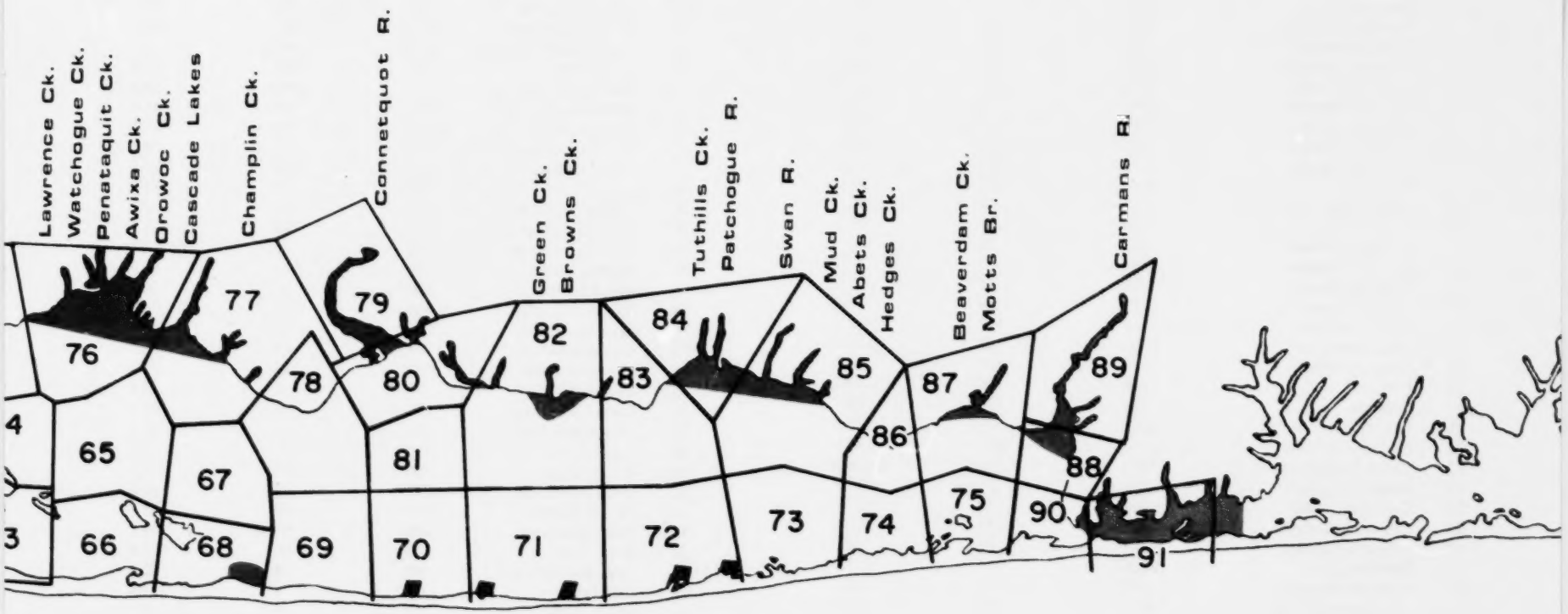
[a]From Nassau County Health Dept. Data

2.3 WATER QUALITY MODEL

The water quality model was set up to run under either steady-state or transient conditions. The boundary conditions and point sources were run at steady state (three runs) because their coliform concentrations fluctuate gradually, if at all. The East Rockaway Inlet boundary was run separately from the other inlets since the coliform levels there are sometimes affected by the New York City sewage treatment plant discharges. The East Rockaway boundary condition was initially taken to be 35 MPN/100 ml, and the other inlets were set at 10 MPN/100 ml. The only point sources of concern to this analysis were located in Node 13 -Bay Park STP and Long Beach STP. This was based on an analysis of flow, discharge quality (Table C-2.0-2), and location. The remaining point sources would have a minuscule effect on the system and were not run in the quality analysis.

Stormwater runoff modeling was done for 35 point locations. Runoff from streams was grouped by node. Shoreline nodes without streams were analyzed for contributing drainage area, and overland runoff was determined. The storm chosen for the initial quality runs was the 2-in. in 12-hr rainfall, a typical frontal event. Storm flows and quality characteristics were taken from Weston (1977) and adjusted for modified contributing drainage areas. Total coliform loadings caused by the storm are presented in Tables C-2.0-1 and C-2.0-3. The quality modeling was carried out in the following manner: first, the stormwater runoff load was "pulsed" into each node (individually) over a one-day period, and then the decay and distribution of coliforms in the bays were tracked for seven more days.


QUEENS CO.
NASSAU CO.
NASSAU CO.
SUFFOLK CO.
Mill Ck.
Parsonage Ck.
Milburn Ck.
E. Meadow Br.
Newbridge Ck.
Cedar Swamp Ck.
Bellmore Ck.
Seamans Ck.
Seaford Ck.
Massapequa Ck.
Unqua (Jones) R.
Carman Ck.
Amityville Ck.
Woods (Ketcham) Ck.
Howell Ck.
Great Neck Ck.
Strongs Ck.
Little Neck Ck.
Neguntatogue Ck.
Santapogue R.
W. Babylon Ck.
Carll's R.
Sampawams Ck.
Skookwams Ck.
Willets Ck.
Trues Ck.
ATLANTIC



CERTIFIED

UNCERTIFIED

SEASONALLY CERTIFIED

52 NODE NUMBER

FIGURE C-2.0-1 *Model segmentation and shellfish areas*

TABLE C-2.0-3

STORM EVENT CHARACTERISTICS

Node	Description	Drainage Area (acres)	Total Coliform Load[a] (trillion MPN)	Portion of Total Load To Node (percent)
2	Overland-Nassau	1623	137	100.0
3	Overland-Nassau	318	22	100.0
4	Overland-Nassau	367	34	100.0
5	Overland-Nassau	227	20	100.0
6	Overland-Nassau	656	38	100.0
8	Overland-Nassau	1298	102	100.0
9	Overland-Nassau	139	1	100.0
10	Overland-Nassau	263	20	100.0
11	Overland-Nassau	271	365	42.2
11	Mill Creek	7692	500	57.8
13	Overland-Nassau	441	44	100.0
14	Overland-Nassau	752	32	10.0
16	Overland-Nassau	703	70	100.0
17	Overland-Nassau	1525	95	39.9
17	Seamans Creek	866	84	35.2
17	Seaford Creek	519	59	24.9
18	Overland-Nassau	1045	117	32.1
18	Parsonage Creek	2995	247	67.9
19	Overland-Nassau	1614	180	60.4
19	Milburn Creek	1366	118	39.6
21	Overland-Nassau	1751	131	24.7
21	East Meadow Brook	6868	399	75.3
23	Overland-Nassau	1410	157	49.6
23	Cedar Swamp Creek	1386	125	39.5
23	Newbridge Creek	372	35	10.9
24	Overland-Nassau	402	10	100.0
26	Overland-Nassau	465	11	100.0
40	Overland-Nassau	871	65	23.0
40	Bellmore Creek	2536	217	77.0
41	Overland-Nassau	601	71	18.5
41	Massapequa Creek	3711	312	81.5
51	Overland-Nassau	756	71	22.7
51	Unqua River	1000	117	37.5
51	Carman Creek	1459	124	39.8
52	Overland-Suffolk	555	45	33.4
52	Amityville Creek	585	48	35.6
52	Woods Creek	351	32	23.6
52	Howell Creek	114	10	7.4
53	Overland-Suffolk	854	79	37.2
53	Great Neck Creek	345	31	14.4
53	Strongs Creek	404	38	18.1
53	Neguntatogue Creek	483	39	18.4
53	Little Neck Creek	253	25	11.9
54	Overland-Suffolk	922	69	10.3
54	Santapogue Creek	2623	219	32.6
54	West Babylon Creek	575	44	6.6
54	Carlls River	4045	340	50.6
55	Overland-Suffolk	613	59	19.9
55	Sampawams Creek	2043	143	48.3
55	Willets Creek	825	75	25.2
55	Skookwans Creek	207	19	6.5
56	Overland-Suffolk	247	14	26.8
56	Trues Creek	429	37	73.2
76	Overland-Suffolk	1129	96	22.2
76	Penataquit Creek	593	40	9.3
76	Watchogue Creek	238	13	3.0
76	Orowoc Creek	2446	195	45.2
76	Awixa Creek	596	35	8.1
76	Cascade Lakes	485	28	6.5
76	Lawrence Creek	236	24	5.6
77	Overland-Suffolk	744	45	26.9
77	Champlin Creek	1533	122	73.1
79	Overland-Suffolk	77	2	6.4
79	Connetquot River	1370	36	93.6
82	Overland-Suffolk	440	31	28.8
82	Green Creek	451	36	33.9
82	Brown Creek	756	40	37.3
84	Overland-Suffolk	893	54	28.3
84	Tuthills Creek	318	22	11.4
84	Patchogue River	930	85	44.7
84	Swan River	408	30	15.6
85	Overland-Suffolk	330	14	85.0
85	Mud Creek	9	1	4.6
85	Abets Creek	11	1	6.1
85	Hedges Creek	9	1	4.6
87	Overland-Suffolk	123	4	57.5
87	Beaverdam Creek	108	2	30.2
87	Motts Brook	27	1	12.3
89	Overland-Suffolk	765	1	93.8
89	Carmans River	594	1	6.2

[a] Load based on 2 inch in 12 hour rainfall Overland loads are based on residential land use (6.2×10^{10} MPN/acre/in. of rain) drainage area which is generally less than total drainage area.

Some of the points to be made here are:

1. The choice of storm is unimportant. The quality results can be factored up or down, depending on the rainfall.
2. The distribution of a 12-hr storm over 24 hrs is reasonable, as the runoff duration for most Long Island streams is generally much longer than 12 hrs.
3. An eight-day period was chosen because (a) most of the coliforms have decayed by that time; (b) the time between storms is generally much less than eight days; and (c) this is the time frame chosen by NYSDEC for opening conditionally certified shellfish beds.

The coliform die-off rate used for this analysis is a conservation 1.0/day at 20°C, based on a statistical analysis of in situ NYSDEC data (Redman 1979). This is also the mean reported value for die-off in fresh water, and is much less than the reported seawater values (Mitchell and Chamberlin 1978).

Output from the quality runs is a matrix for each discharge location. Each row is the daily coliform concentration in a node over eight days. These data are used as input to the Matrix Manipulation Model.

CHAPTER C-3.0

MATRIX MANIPULATION MODEL

The Matrix Manipulation Model (MMM) is a viable tool for assessing long-term quality characteristics of the South Shore/Great South Bay System. To better understand the assumptions and use of the model, some of the mathematics are explained in the following paragraphs.

3.1 MODEL FORMULATION

3.1.1 Mathematical Derivation. The equations of mass that govern the movement of water quality constituents in just about any system are linear; for example, the effect of two separate discharges on a bay is the sum of their individual effects. First, define the concentration in the bay as a function of time, C(t). Then define the effect of unit discharge No. 1 as $C_1(t)$ and unit discharge No. 2 as $C_2(t)$. If C_1 and C_2 began at the same time (t = 0) and C(0) = , then the equation would be $C(t) = C_1(t) + C_2(t)$. If the second discharge began at a later time (t_2), the equation would be $C(t) = C_1(t) + C_2(t\text{-}t_2)$. If the discharge at No. 1 was twice the unit discharge, the equation would be $C(t) = 2C_1(t) + C_2(t\text{-}t_2)$, and so on. Now divide the bay into N nodes with M discharges. The bay concentration in Node i would be C(i,t). Assume the background and initial conditions as a function of time are $C_o(i,t)$ and the effect of unit discharge j is $C_j(i,t)$. Then the equation for the concentration in Node i at any time t is:

$$C(i,t) = C_0(it,) + \sum_{J=1}^{M} F_j C_j(i,t)$$

where f_j is a factor to increase or decrease the effect of unit discharge j. This is the basic theory in MMM.

3.1.2 Quality Matrices. The output from the 208 quality runs is stored in matrices (data files) for use in MMM. The first is the steady-state (background or boundary condition) matrix. This has 99 rows (one for each node) and three columns (East Rockaway Inlet, other inlets, and Node 13 STPs). These data are presented in Table C-3.0-1. The second matrix is composed of 99 rows and eight columns for each of the 35 unit discharges. Each column is the concentration in that node (row) for the given day (column) as a result of the specific unit discharge, making this a transient matrix. Table C-3.0-2 presents the matrix for discharges to Node 11 (in Nassau), and Table C-3.0-3 presents the matrix for discharges to Node 87 (in Suffolk). General observation of the two matrices brings forth a point that will become significant when looking at mitigating measures (for reopening shellfish beds): the stream discharges in Nassau have a very small effect on the nodes in Suffolk. The converse also holds: the Suffolk runoff has little effect on nodes in Nassau.

3.2 MODEL ASSUMPTIONS

3.2.1 Purpose. Rather than looking at individual storms, it is advantageous to look at a continuous simulation of a period of storms. In this manner it is possible to generate statistics on, for example, the number of days a year a shellfish bed is open, thus providing a base for cost-effectiveness analyses of control measures. By designing MMM to run for a year, a high reliability can be placed on the statistical validity of the generated numbers.

3.2.2 Generation of Storms. By knowing the mean, standard deviation, and statistical distribution of rainfall, it is possible to randomly generate storms that, over the long run, are representative of the area. A recent publication (EPA 1979) shows that both total rainfall (in./storm) and the time between storms have a gamma distribution. If the coefficient of variation (standard deviation divided by the mean) is unity, the gamma distribution reduces to an exponential distribution.

An exponential distribution is of the form $P(x) = e^{-x/u}$, where u = mean value, x = independent value, and P(x) is the probability that an observation will be greater than x. For example, if u = 0.43 in., the probability that a storm will be greater than 1.25 in. is $e^{-1.25/.43} = 0.05$. It naturally follows that the probability of a storm's being less than or equal to 1.25 in. is 1.0 - 0.05 = 0.95.

Table C-3.0-1

STEADY-STATE MATRIX OF MMM

Node	Concentrations (MPN/100 ml) East Rockaway Inlet	Other Inlets	Node 13 Discharges	Node	Concentrations (MPN/100 ml) East Rockaway Inlet	Other Inlets	Node 13 Discharges	Node	Concentrations (MPN/100 ml) East Rockaway Inlet	Other Inlets	Node 13 Discharges
1	18.9	.0	.6	34	.0	.6	.0	67	.0	.0	.0
2	9.3	.1	1.4	35	.0	.2	.0	68	.0	.0	.0
3	4.9	.1	2.5	36	.0	.1	.0	69	.0	.0	.0
4	2.6	.2	4.0	37	.0	.2	.0	70	.0	.0	.0
5	.7	.0	1.2	38	.0	.1	.0	71	.0	.0	.0
6	.6	.0	1.0	39	.0	.3	.0	72	.0	.0	.0
7	1.5	.1	2.5	40	.0	.1	.0	73	.0	.0	.0
8	.1	.0	.4	41	.0	.0	.0	74	.0	.0	.0
9	.1	.3	.5	42	.0	.0	.0	75	.0	.0	.0
10	.0	.0	.2	43	.0	.0	.0	76	.0	.0	.0
11	.1	.1	1.3	44	.0	.0	.0	77	.0	.0	.0
12	.6	.2	4.8	45	.0	.0	.0	78	.0	.0	.0
13	.9	.3	8.2	46	.0	.0	.0	79	.0	.0	.0
14	.3	.1	2.7	47	.0	.0	.0	80	.0	.0	.0
15	.5	.1	1.6	48	.0	.0	.0	81	.0	.0	.0
16	.2	.7	1.8	49	.0	.0	.0	82	.0	.0	.0
17	.0	.1	.0	50	.0	.0	.0	83	.0	.0	.0
18	.0	.2	.2	51	.0	.0	.0	84	.0	.0	.0
19	.0	.5	.0	52	.0	.0	.0	85	.0	.0	.0
20	.0	.9	.0	53	.0	.0	.0	86	.0	.0	.0
21	.0	.5	.0	54	.0	.0	.0	87	.0	.0	.0
22	.0	.3	.0	55	.0	.0	.0	88	.0	.0	.0
23	.0	.1	.0	56	.0	.0	.0	89	.0	.0	.0
24	.0	1.5	.4	57	.0	.0	.0	90	.0	.0	.0
25	.0	.6	.2	58	.0	.0	.0	91	.0	.0	.0
26	.0	2.5	.1	59	.0	.0	.0	92	.0	.0	.0
27	.0	2.5	.1	60	.0	.0	.0	93	.0	.1	.0
28	.0	4.0	.0	61	.0	4.9	.0	94	.0	.5	.0
29	.0	7.2	.0	62	.0	.9	.0	95	.0	2.3	.0
30	.0	1.4	.0	63	.0	.2	.0	96	.0	.8	.0
31	.0	2.4	.0	64	.0	.0	.0	97	.0	.3	.0
32	.0	.6	.0	65	.0	.0	.0	98	.0	.1	.0
33	.0	1.3	.0	66	.0	.0	.0	99	.0	3.7	.0

Table C-3.0-2

MMM TRANSIENT MATRIX, DISCHARGE TO NODE 11

Node	Concentration (MPN/100 ml)							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
1	1.7	11.2	11.6	5.9	2.3	.8	.3	.1
2	6.5	31.1	26.7	12.5	4.8	1.7	.6	.2
3	18.1	59.4	41.3	17.9	6.6	2.3	.8	.2
4	44.2	99.1	56.2	22.5	8.0	2.7	.9	.3
5	5.6	32.8	36.3	20.9	9.2	3.6	1.3	.4
6	6.8	35.9	39.4	23.0	10.3	4.0	1.5	.5
7	30.6	92.7	61.8	26.8	10.1	3.6	1.2	.4
8	105.5	221.5	143.4	64.2	24.7	8.8	3.0	1.0
9	203.4	340.4	133.0	42.6	13.1	4.0	1.2	.4
10	1106.2	864.6	337.6	116.7	38.8	12.7	4.1	1.4
11	22300.9	3258.0	618.4	135.5	33.6	9.2	2.7	.8
12	830.7	594.9	169.6	47.0	13.7	4.2	1.3	.4
13	141.0	185.3	77.8	26.9	8.9	2.9	.9	.3
14	4761.0	1793.4	383.9	88.3	22.6	6.3	1.9	.6
15	176.0	292.7	142.5	53.6	18.8	6.4	2.1	.7
16	29.5	92.2	54.9	21.3	7.3	2.4	.8	.2
17	.0	.0	.0	.0	.0	.0	.0	.0
18	37.7	151.3	94.6	36.5	12.2	3.9	1.2	.4
19	1.4	12.5	14.8	8.5	3.6	1.3	.5	.2
20	.1	1.4	2.5	1.9	1.0	.4	.2	.1
21	.0	.3	.9	.9	.6	.3	.1	.0
22	.0	.1	.3	.4	.3	.2	.1	.0
23	.0	.0	.1	.1	.1	.1	.0	.0
24	7.8	33.2	24.2	10.5	3.8	1.3	4.	.1
25	4.5	37.1	39.9	20.4	7.9	2.7	.9	.3
26	1.4	9.8	9.6	4.8	1.9	.7	.2	.1
27	.1	1.1	1.9	1.3	.7	.3	.1	.0
28	.1	.9	1.3	.8	.4	.2	.1	.0
29	.0	.3	.4	.3	.1	.1	.0	.0
30	.0	.4	1.1	.9	.5	.2	.1	.0
31	.0	.4	.8	.6	.3	.1	.1	.0
32	.0	.1	.2	.2	.2	.1	.0	.0
33	.0	.1	.4	.4	.2	.1	.0	.0
34	.0	.0	.1	.2	.1	.1	.0	.0
35	.0	.0	.0	.0	.0	.0	.0	.0
36	.0	.0	.0	.0	.0	.0	.0	.0
37	.0	.0	.0	.1	.1	.0	.0	.0
38	.0	.0	.0	.0	.0	.0	.0	.0
39	.0	.0	.1	.1	.1	.0	.0	.0
40	.0	.0	.0	.0	.0	.0	.0	.0
41	.0	.0	.0	.0	.0	.0	.0	.0
42	.0	.0	.0	.0	.0	.0	.0	.0
43	.0	.0	.0	.0	.0	.0	.0	.0
44	.0	.0	.0	.0	.0	.0	.0	.0
45	.0	.0	.0	.0	.0	.0	.0	.0
46	.0	.0	.0	.0	.0	.0	.0	.0
47	.0	.0	.0	.0	.0	.0	.0	.0
48	.0	.0	.0	.0	.0	.0	.0	.0
49	.0	.0	.0	.0	.0	.0	.0	.0
50	.0	.0	.0	.0	.0	.0	.0	.0

Node	Concentration (MPN/100 ml)							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
51	.0	.0	.0	.0	.0	.0	.0	.0
52	.0	.0	.0	.0	.0	.0	.0	.0
53	.0	.0	.0	.0	.0	.0	.0	.0
54	.0	.0	.0	.0	.0	.0	.0	.0
55	.0	.0	.0	.0	.0	.0	.0	.0
56	.0	.0	.0	.0	.0	.0	.0	.0
57	.0	.0	.0	.0	.0	.0	.0	.0
58	.0	.0	.0	.0	.0	.0	.0	.0
59	.0	.0	.0	.0	.0	.0	.0	.0
60	.0	.0	.0	.0	.0	.0	.0	.0
61	.0	.0	.0	.0	.0	.0	.0	.0
62	.0	.0	.0	.0	.0	.0	.0	.0
63	.0	.0	.0	.0	.0	.0	.0	.0
64	.0	.0	.0	.0	.0	.0	.0	.0
65	.0	.0	.0	.0	.0	.0	.0	.0
66	.0	.0	.0	.0	.0	.0	.0	.0
67	.0	.0	.0	.0	.0	.0	.0	.0
68	.0	.0	.0	.0	.0	.0	.0	.0
69	.0	.0	.0	.0	.0	.0	.0	.0
70	.0	.0	.0	.0	.0	.0	.0	.0
71	.0	.0	.0	.0	.0	.0	.0	.0
72	.0	.0	.0	.0	.0	.0	.0	.0
73	.0	.0	.0	.0	.0	.0	.0	.0
74	.0	.0	.0	.0	.0	.0	.0	.0
75	.0	.0	.0	.0	.0	.0	.0	.0
76	.0	.0	.0	.0	.0	.0	.0	.0
77	.0	.0	.0	.0	.0	.0	.0	.0
78	.0	.0	.0	.0	.0	.0	.0	.0
79	.0	.0	.0	.0	.0	.0	.0	.0
80	.0	.0	.0	.0	.0	.0	.0	.0
81	.0	.0	.0	.0	.0	.0	.0	.0
82	.0	.0	.0	.0	.0	.0	.0	.0
83	.0	.0	.0	.0	.0	.0	.0	.0
84	.0	.0	.0	.0	.0	.0	.0	.0
85	.0	.0	.0	.0	.0	.0	.0	.0
86	.0	.0	.0	.0	.0	.0	.0	.0
87	.0	.0	.0	.0	.0	.0	.0	.0
88	.0	.0	.0	.0	.0	.0	.0	.0
89	.0	.0	.0	.0	.0	.0	.0	.0
90	.0	.0	.0	.0	.0	.0	.0	.0
91	.0	.0	.0	.0	.0	.0	.0	.0
92	.0	.0	.0	.0	.0	.0	.0	.0
93	.0	.0	.0	.0	.0	.0	.0	.0
94	.0	.0	.0	.0	.0	.0	.0	.0
95	.0	.0	.0	.0	.0	.0	.0	.0
96	.0	.0	.0	.0	.0	.0	.0	.0
97	.0	.0	.0	.0	.0	.0	.0	.0
98	.0	.0	.0	.0	.0	.0	.0	.0
99	.0	.0	.0	.0	.0	.0	.0	.0

Table C-3.0-3

MMM TRANSIENT MATRIX, DISCHARGE TO NODE 87

Node	Concentration (MPN/100 ml)								Node	Concentration (MPN/100 ml)							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
1	.0	.0	.0	.0	.0	.0	.0	.0	51	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	52	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	.0	53	.0	.0	.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	.0	54	.0	.0	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	55	.0	.0	.0	.0	.0	.0	.0	.0
6	.0	.0	.0	.0	.0	.0	.0	.0	56	.0	.0	.0	.0	.0	.0	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	.0	57	.0	.0	.0	.0	.0	.0	.0	.0
8	.0	.0	.0	.0	.0	.0	.0	.0	58	.0	.0	.0	.0	.0	.0	.0	.0
9	.0	.0	.0	.0	.0	.0	.0	.0	59	.0	.0	.0	.0	.0	.0	.0	.0
10	.0	.0	.0	.0	.0	.0	.0	.0	60	.0	.0	.0	.0	.0	.0	.0	.0
11	.0	.0	.0	.0	.0	.0	.0	.0	61	.0	.0	.0	.0	.0	.0	.0	.0
12	.0	.0	.0	.0	.0	.0	.0	.0	62	.0	.0	.0	.0	.0	.0	.0	.0
13	.0	.0	.0	.0	.0	.0	.0	.0	63	.0	.0	.0	.0	.0	.0	.0	.0
14	.0	.0	.0	.0	.0	.0	.0	.0	64	.0	.0	.0	.0	.0	.0	.0	.0
15	.0	.0	.0	.0	.0	.0	.0	.0	65	.0	.0	.0	.0	.0	.0	.0	.0
16	.0	.0	.0	.0	.0	.0	.0	.0	66	.0	.0	.0	.0	.0	.0	.0	.0
17	.0	.0	.0	.0	.0	.0	.0	.0	67	.0	.0	.0	.0	.0	.0	.0	.0
18	.0	.0	.0	.0	.0	.0	.0	.0	68	.0	.0	.0	.0	.0	.0	.0	.0
19	.0	.0	.0	.0	.0	.0	.0	.0	69	.0	.0	.0	.0	.0	.0	.0	.0
20	.0	.0	.0	.0	.0	.0	.0	.0	70	.0	.0	.0	.0	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	.0	.0	71	.0	.0	.0	.0	.0	.0	.0	.0
22	.0	.0	.0	.0	.0	.0	.0	.0	72	.0	.0	.0	.0	.0	.0	.0	.0
23	.0	.0	.0	.0	.0	.0	.0	.0	73	.0	.0	.1	.1	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	.0	.0	74	.8	2.2	1.9	1.2	.6	.3	.1	.1
25	.0	.0	.0	.0	.0	.0	.0	.0	75	16.8	18.7	10.1	4.6	1.9	.8	.3	.1
26	.0	.0	.0	.0	.0	.0	.0	.0	76	.0	.0	.0	.0	.0	.0	.0	.0
27	.0	.0	.0	.0	.0	.0	.0	.0	77	.0	.0	.0	.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	.0	.0	78	.0	.0	.0	.0	.0	.0	.0	.0
29	.0	.0	.0	.0	.0	.0	.0	.0	79	.0	.0	.0	.0	.0	.0	.0	.0
30	.0	.0	.0	.0	.0	.0	.0	.0	80	.0	.0	.0	.0	.0	.0	.0	.0
31	.0	.0	.0	.0	.0	.0	.0	.0	81	.0	.0	.0	.0	.0	.0	.0	.0
32	.0	.0	.0	.0	.0	.0	.0	.0	82	.0	.0	.0	.0	.0	.0	.0	.0
33	.0	.0	.0	.0	.0	.0	.0	.0	83	.0	.0	.0	.0	.0	.0	.0	.0
34	.0	.0	.0	.0	.0	.0	.0	.0	84	.0	.0	.0	.0	.0	.0	.0	.0
35	.0	.0	.0	.0	.0	.0	.0	.0	85	.1	.3	.3	.2	.1	.0	.0	.0
36	.0	.0	.0	.0	.0	.0	.0	.0	86	26.0	17.7	9.5	4.2	1.7	.7	.3	.1
37	.0	.0	.0	.0	.0	.0	.0	.0	87	549.7	173.4	55.3	17.9	5.8	1.9	.6	.2
38	.0	.0	.0	.0	.0	.0	.0	.0	88	21.4	22.7	11.7	5.1	2.0	.8	.3	.1
39	.0	.0	.0	.0	.0	.0	.0	.0	89	1.7	4.3	3.6	2.1	1.0	.5	.2	.1
40	.0	.0	.0	.0	.0	.0	.0	.0	90	2.1	5.2	4.3	2.4	1.2	.5	.2	.1
41	.0	.0	.0	.0	.0	.0	.0	.0	91	.0	.0	.1	.0	.0	.0	.0	.0
42	.0	.0	.0	.0	.0	.0	.0	.0	92	.0	.0	.0	.0	.0	.0	.0	.0
43	.0	.0	.0	.0	.0	.0	.0	.0	93	.0	.0	.0	.0	.0	.0	.0	.0
44	.0	.0	.0	.0	.0	.0	.0	.0	94	.0	.0	.0	.0	.0	.0	.0	.0
45	.0	.0	.0	.0	.0	.0	.0	.0	95	.0	.0	.0	.0	.0	.0	.0	.0
46	.0	.0	.0	.0	.0	.0	.0	.0	96	.0	.0	.0	.0	.0	.0	.0	.0
47	.0	.0	.0	.0	.0	.0	.0	.0	97	.0	.0	.0	.0	.0	.0	.0	.0
48	.0	.0	.0	.0	.0	.0	.0	.0	98	.0	.0	.0	.0	.0	.0	.0	.0
49	.0	.0	.0	.0	.0	.0	.0	.0	99	.0	.0	.0	.0	.0	.0	.0	.0
50	.0	.0	.0	.0	.0	.0	.0	.0									

Table C-3.0-4

LONG ISLAND RAIN GAUGE STATISTICS

Name	Period of Record	Volume (in.)		Intensity (in./hr)		Duration (hr)		Hours Between Storms	
		Mean[a]	CV[b]	Mean	CV	Mean	CV	Mean	CV
Mineola	1962–1978	0.4326	1.343	0.0878	1.137	5.83	1.303	88.9	0.991
Wantagh	1976–1978	0.4007	1.542	0.0754	1.235	5.55	1.027	82.9	1.027
Upton	1948–1978	0.4314	1.416	0.0761	1.060	6.28	1.093	80.6	0.988

[a] Mean volume does not equal mean intensity times mean duration because analysis was performed on hourly data.
[b] CV = Coefficient of variation.

In an exponential distribution, the probability that a value is less than or equal to the mean is 0.63; in other words, 63% of the storms will be at or below the mean.

Data taken at various Long Island rain gauges support an exponential distribution. Table C-3.0-4 shows data from three rain gauges that have been run through a statistical analysis (SYNOP). The station at Upton was chosen for the model because it had the longest period of record.

The model calculates storms in the following manner: first, it generates two uniformly distributed random numbers (between zero and one). Second, it takes the natural log of these numbers and multiplies them by the negative of the mean rainfall (0.43 in.) and lag time (80.6 hrs). This is the transformation from uniformly distributed to exponentially distributed random numbers. MMM then applies this storm to the whole drainage area, does the computations for each of the unit discharges, multiplies by the appropriate factor (inches of rain generated/inches of rain per unit discharge), and sums up the results. A new storm is not applied until the computed lag time has passed.

A question may arise about the use of a constant storm over the whole island. Suppose the assumption is made that Nassau and Suffolk do have different storms at different times, but overall the mean rainfall (both annual and per storm) is about the same. A separate random distribution of storms for Nassau and Suffolk could be run, but one random distribution is as good as another, so the same distribution could be used for both areas. Even with separate distributions, after running the model for a year, the probability density function for both areas would be roughly the same. This, coupled with the fact that Nassau discharges affect Suffolk nodes very little, and vice versa (see Section 3.1.2), makes the assumption of uniform rainfall distribution in the model valid.

During lag times between storms, there is a background loading to the bays incorporated in the model. This is the summer baseflows and associated coliform loadings.

At the beginning of a yearly simulation, the model generates zero, one, or two storms over the previous week to serve as initial conditions. This is done in the same manner as described previously.

All random number sequences that are generated in the model are reproducible; by starting with the same "seed," or initial value, the same sequence of numbers is used. This reproducibility is required for control measure analysis.

3.2.3 Split Nodes. Some of the nearshore nodes, mainly in Suffolk, contain both closed and open shellfish areas. Since MMM computes the daily average concentration in a node, some of the closed areas are not accurately represented. To account for this, MMM subdivides these nodes. The equation used is:

$$C = f_A C_A + f_B C_B$$

where
- C = average nodal concentration
- f_A = fraction of node (by surface area) that is uncertified
- C_A = uncertified concentration
- f_B = fraction of node that is certified
- C_B = certified concentration

This is one equation with two unknowns, C_A and C_B. If we let $C_A/C_B = F$, where F is known, then the equation can be solved. The result is $C_A = C/(f_A + f_B/F)$, and $C_B = C_A/F$. The functions f_A and f_B can be obtained by overlaying the nodal geometry and shellfish maps. Table C-3.0-5 presents those nodes that are divided up in this manner. F was obtained by analysis of Nassau County Department of Health bacteriological data. NCDH has many stations, which have been sampled at least once a month for a minimum of five years. By looking at stations in uncertified and certified portions of a node, total coliform data gave an F of 5.2, which is used in this model.

3.2.4 Varying Decay Coefficients. MMM can alter the coliform decay rates by using the average monthly water temperature in the bays. At the present time, this feature is not used. The temperature variation changes the model concentrations by only about 10%, with the change being the same for both baseline and alternative conditions. With respect to the criteria for closing shellfish beds (see Section 3.3.2), there is virtually no change.

Table C-3.0-5

NODES THAT CONTAIN CERTIFIED AND UNCERTIFIED SHELLFISH BEDS

Node	Surface Area	Percent Uncertified	Split in MMM	
51	1905	47	yes	
52	1354	32	yes	
53	1860	36	yes	
54	1837	66	yes	
55	1814	46	yes	
76	2824	36	yes	
77	2502	14	yes	
84	1194	38	yes	
85	2319	10	yes	
28	551	29	no	
30	298	89	no	
31	413	12	no	Reason-cleanup of
32	298	20	no	nearshore nodes will
34	253	65	no	automatically certify
37	482	53	no	these nodes.
39	275	55	no	
88	689	31	no	

3.3 MODEL OUTPUT AND ANALYSIS

3.3.1 Output. The model generates coliform concentrations over a period of a year. Instead of looking at each day separately, it is advantageous to look at the probability distribution of the nodal concentration. The model does two sets of analyses for final printout. First, it computes the yearly log-mean concentration in the nodes. This can be compared with actual, long-term data to be sure the MMM is representing the system correctly. Second, it generates a probability distribution of daily concentrations. It compares the nodal concentration with a set of specific values to see if any number of interest is exceeded (70 MPN/100 ml, for example). At the end of the yearly simulation, it prints out both the percentage of time that a given concentration was exceeded and the actual number of days. It does this for all nodes, and also separately for the certified and uncertified portions of the *split* nodes. The model also prints out the number of inches of rainfall and number of storms generated during the year for comparative purposes. Table C-3.0-6 presents a sample model output.

Table C-3.0-6

MMM SAMPLE MODEL OUTPUT

Percent of Node	Total Loads Used Percent
2	100.0
3	100.0
4	100.0
5	100.0
6	100.0
8	100.0
9	100.0
10	100.0
11	100.0
13	100.0
14	100.0
16	100.0
17	100.0
18	100.0
19	100.0
21	100.0
23	100.0
24	100.0
26	100.0
40	100.0
41	100.0
51	100.0
52	100.0
53	100.0
54	100.0
55	100.0
56	100.0
76	100.0
77	100.0
79	100.0
82	100.0
84	100.0
85	100.0
87	100.0
89	100.0
East Rockaway inlet factor	1.00
Other inlets	1.00
Bay Park STP factor	1.00
Random number seed:	82155.0
Storm frequency factor:	1.08
Max. storm controlled (in):	5.000

Table C-3.0-6 (Cont'd)

MMM SAMPLE MODEL OUTPUT

Node	Percent of Time MPN/100 ml Exceeded									
	10	70	230	330	500	1000	2400	5000	10000	15000
11	100.00	70.41	51.78	48.22	43.29	35.34	24.38	13.70	4.66	2.19
18	75.89	53.70	37.26	32.88	25.75	13.70	3.29	.27	.00	.00
41	78.36	58.90	42.74	35.34	28.77	15.62	3.56	.27	.00	.00
54	100.00	61.10	38.08	31.51	23.56	11.51	1.37	.00	.00	.00
76	100.00	40.82	13.15	7.95	3.29	.27	.00	.00	.00	.00

Node	Number of Days MPN/100 ml Exceeded									
	10	70	230	330	500	1000	2400	5000	10000	15000
11	365	257	189	176	158	129	89	50	17	8
18	277	196	136	120	94	50	12	1	0	0
41	286	215	156	129	105	57	13	1	0	0
54	365	223	139	115	86	42	5	0	0	0
76	365	149	48	29	12	1	0	0	0	0

Node No.	Log Mean Conc. MPN/100 ml	All Storm Analysis Certified		WPC Analysis Certified		WPC Days (Storm + 2 Days)	
		At 70	At 230	At 70	At 230	70	230
11	396.4	No	No	No	No	148	132
18	91.1	No	No	No	No	139	106
41	104.5	No	No	No	No	148	120
54	144.7	No	No	No	No	148	111
76	66.1	No	No	No	No	121	48

Total inches of rain generated:	51.4
Total number of storms:	118
Total No. of storms ¼ inch:	73
Total No. of worst poll. cond.	148

SPLIT NODES—UNCERTIFIED AREAS

Node	Percent of Time MPN/100 ml Exceeded									
	10	70	230	330	500	1000	2400	5000	10000	15000
54	100.00	66.03	45.21	36.71	29.86	15.89	3.56	.27	.00	.00
76	100.00	62.74	29.59	20.55	12.88	3.56	.27	.00	.00	.00

SPLIT NODES—CERTIFIED AREAS

Node	Percent of Time MPN/100 ml Exceeded									
	10	70	230	330	500	1000	2400	5000	10000	15000
54	72.88	35.62	12.88	7.95	3.29	.27	.00	.00	.00	.00
76	98.36	17.53	2.47	.27	.27	.00	.00	.00	.00	.00

NUMBER OF DAYS MPN/100 ml EXCEEDED

Node	Percent of Time MPN/100 ml Exceeded									
	10	70	230	330	500	1000	2400	5000	10000	15000
54	365	241	165	134	109	58	13	1	0	0
76	365	229	108	75	47	13	1	0	0	0

NUMBER OF DAYS MPN/100 ml EXCEEDED

Node	Percent of Time MPN/100 ml Exceeded									
	10	70	230	330	500	1000	2400	5000	10000	15000
54	266	130	47	29	12	1	0	0	0	0
76	359	64	9	1	1	0	0	0	0	0

Node No.	Log Mean Conc. MPN/100 ml	All Storm Analysis Certified		WPC Analysis Certified		WPC Days (Storm + 2 Days)	
		At 70	At 230	At 70	At 230	70	230
54	199.1	No	No	No	No	148	126
76	136.4	No	No	No	No	148	97

Node No.	Log Mean Conc. MPN/100 ml	All Storm Analysis Certified		WPC Analysis Certified		WPC Days (Storm + 2 Days)	
		At 70	At 230	At 70	At 230	70	230
54	39.1	No	Yes	No	No	107	47
76	26.6	No	Yes	Yes	Yes	64	9

3.3.2 Analysis of Output. The interpretation of the model results could have a substantial effect on the cost-benefit analysis of control measures. For example, one might wish the long-term geometric mean to be under 70 MPN/100 ml, or the median, or simply to have the concentrations meeting standards a given number of days per year. The delimiter chosen will influence the amount of reduction of coliform loadings to the bay needed to meet the standard.

NYSDEC looks at coliform data in shellfish areas and determines worst pollution conditions (WPC). Generally, for Long Island, WPC occur following rainfall. NYSDEC then analyzes only the data taken during WPC, and if the standards are violated, the bed is closed (Redman 1981). WPC consist of the day of and two days following a storm greater than 0.25 in. of rain.

There are two primary NYSDEC criteria for keeping shellfish beds open. The first criterion is that 50% or more of the data taken during WPC must be less than 70 MPN/100 ml. The other NYSDEC standard considered is that 10% of the data cannot exceed 230 MPN/100 ml. This means that the number of WPC where 230 MPN/100 ml is exceeded must be less than one-tenth of the number of WPC generated.

The average coliform concentration in a node over a year would not be valid in comparisons with state standards; rather, the number of days per year that 70 MPN/100 ml is exceeded is of importance. This should be compared with the number of WPC generted per year. Since the 70 MPN/100 ml is a median value, if the number of days it is exceeded is less than half the number of WPC, the shellfish bed can be considered open. For example, if 100 WPC are generated, we are looking for 50 or fewer days that 70 MPN is exceeded.

It is interesting to note that, because of the manner in which NYSDEC regulations are written, control measures need not be designed to handle all storms. For example, if 150 WPC occur over a year, 75 of them must have coliform values less than 70 MPN/100 ml to consider the shellfish beds open. Since many more small storms occur than large storms, and the maximum WPC per storm is three (meaning that WPC are independent of storm size), some of the larger storms can be ignored. This has been included in MMM. A design rainfall can be input, and runoff is controlled up to the design limit - any excess is not controlled. There is a slight tradeoff in ignoring the larger storms, however, the 10% - 230 MPN/100 ml criterion is more apt to be violated. Figure C-2.0-1 shows the shellfish beds that are considered closed by NYSDEC. In this analysis, only those areas west of Carmans River are being considered, as drainage areas and loads have not been developed for the Moriches area (Node 91 and east).

CHAPTER C-4.0

VERIFICATION OF MMM

4.1 INTRODUCTION

To ensure that the developed model accurately and reliably represents the system, a series of analyses was done. These included testing model results against actual data, the statistical reliability of the model, and the effect of wet and normal years on the model results.

4.2 COMPARISON OF MMM TO ACTUAL DATA

Since MMM is based on the 208 models (Tetra Tech 1977a), which used historical average data up to 1976 for point sources and runoff loads, it was decided to compare model results with actual 1976 data. NCDH has a substantial number of bacteriological sampling stations in the South Shore Bays, which are sampled frequently (at least once a month). The yearly geometric mean of these data provided a good data base for model comparison.

The procedure was relatively simple. First, NCDH sampling stations were designated by model node. The yearly log-average for each station (NCDH 1976) was then plotted (Figure C-4.0-1). Next, MMM was modified slightly to accept actual rainfall data instead of generating data. Daily rainfall at the Upton gauge was used, and any gaps that existed in the data were supplemented by NCDH rainfall measurements taken during the time of sampling. Last, the point sources and boundary conditions were adjusted to represent the 1976 conditions.

The model was then run for one year. The results are shown in Figures C-4.0-2 and C-4.0-3. The model and data are in near-perfect agreement. Not only are the coliform concentrations at the same level, but the trends (decreasing west to east) are also predicted. This comparison shows that the model is definitely acting like the prototype system.

Equivalent data were not available on the Suffolk streams. However, with the exception of Carmans River, the model is in agreement with respect to the open and closed shellfish beds. For the Carmans River area, there appears to be an unquantifiable source of coliforms that causes the area to be closed to shellfishing.

4.3 RELIABILITY OF MMM

The reliability of model predictions is important when one considers the possible effects on a cost-benefit analysis from an incorrect or highly variable result. Since it was shown in Section 4.2 that the model does reproduce actual data, the only other point of concern would be the forcing function that generates data.

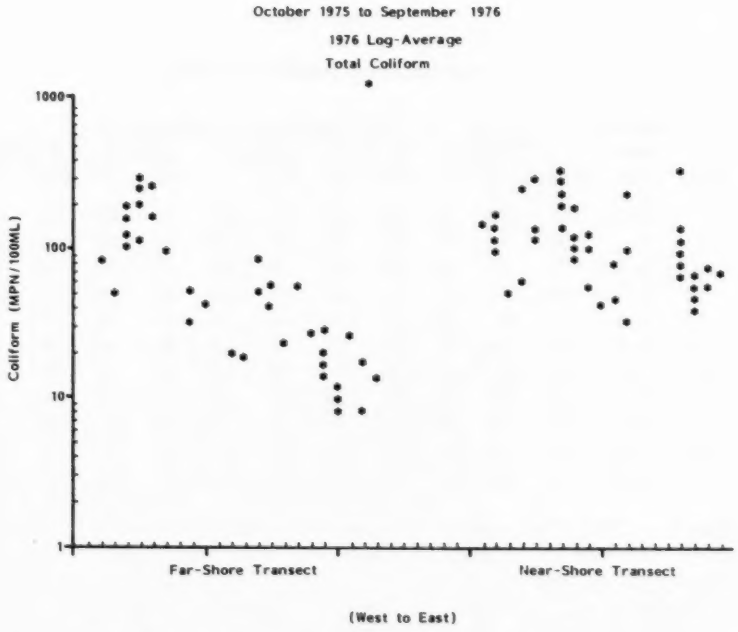


FIGURE C-4.0-1 *Nassau County coliform data*

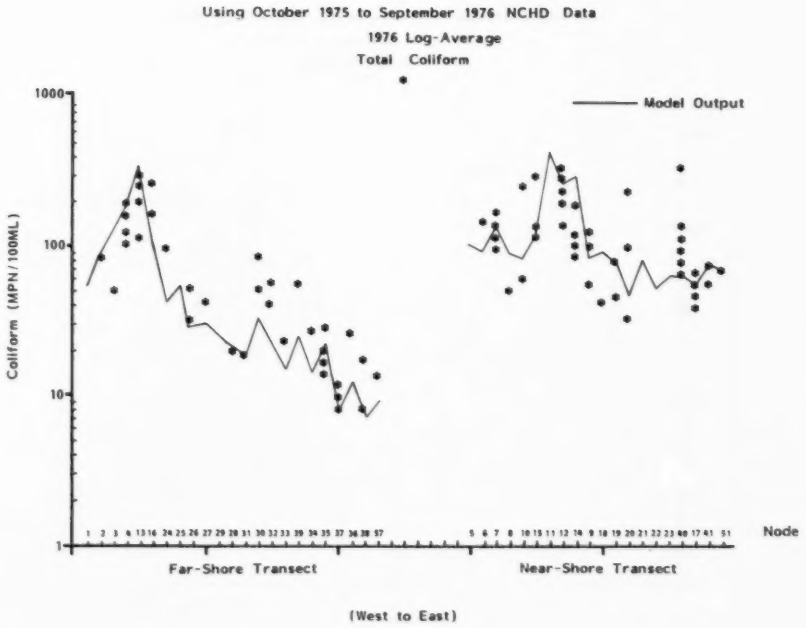


FIGURE C-4.0-2 *Verification run of matrix manipulation model*

In this case, the forcing function is the random sequence of storms. The primary question is what effect would a radically different sequence of storms, having the same annual rainfall, have on the amount of load reduction needed to open shellfish beds. To answer this, 11 different storm sequences were run, using a different "*seed*" to start the random number generator. A 95% reduction in runoff loads was used, and specific nodes were analyzed for closure.

These results are shown in Table C-4.0-1. The ratio of number of WPC days with concentrations greater than 70 MPN per 100 ml to the total number of WPC days is the indicator of node closure. If this ratio is less than 0.5, the node can be considered open for shellfishing.

The results are highly consistent. Those nodes with a mean ratio somewhat higher than 0.5 remained closed, while those with a somewhat lower ratio remained open. When the ratio is very close to 0.5, the closure fluctuates from run to run, which is to be expected. This simply says that we must design load reductions with some factor of safety to account for natural rainfall variation.

The 95% confidence limits provide this factor of safety. These are statistical points about a mean, based on the standard deviation, which represent a 95% confidence that a value will fall within this range. Conversely, 5% of the values will be outside this range. This mean range of these limits in Table C-4.0-1 is 0.13; this means that a ratio of 0.43 (limits of 0.36, 0.50) will give a reasonable factor of safety. If control measures are designed based on this ratio, the shellfish beds can be open 95 out of every 100 years.

The load reductions that are needed to reopen shellfish beds will include the factor of safety. This factor need not be incorporated into the design of control measures.

4.4 EFFECT OF TOTAL RAINFALL ON MODEL RESULTS

In addition to the accuracy and reliability of the model, it is important to know what effect the amount of yearly rainfall has on the results—specifically, opening and closing of shellfish beds. To do this, the model was run for two different rainfalls, with zero and 95% coliform load reduction.

The results of these four runs are shown in Table C-4.0-2. In terms of shellfish bed openings and closings, there is no difference between a year with 45.9 in. of rain and one with 51.3 in. This is due to the manner in which the New York State regulations were written — looking only at the coliform concentrations following storms. The yearly mean concentration in any node, however, will generally be higher with more rainfall.

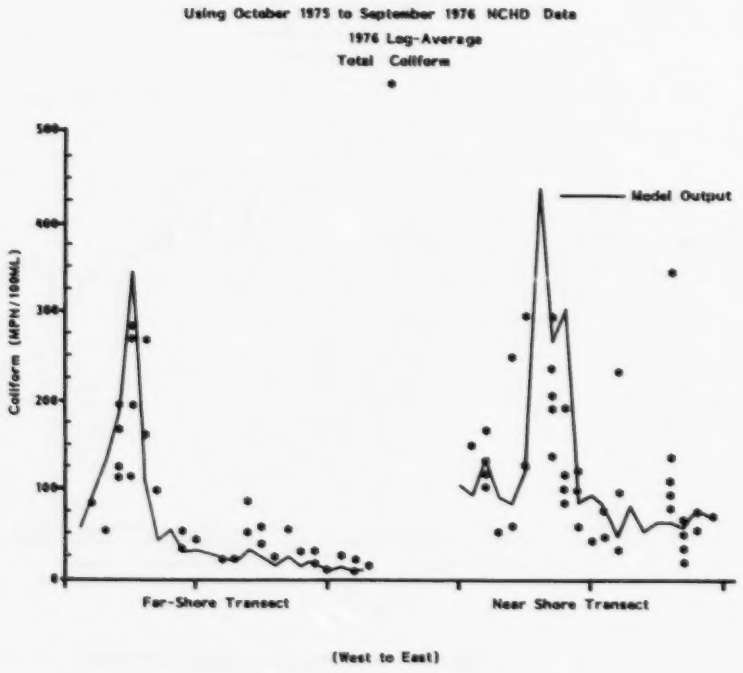


FIGURE C-4.0-3 *Verification run of matrix manipulation model*

Table C-4.0-1

STATISTICAL RELIABILITY OF MMM

Run	Annual Rain (in)	WPC	95% Reduction of All Storm Loads									
			Node 11		Node 18		Node 41		Node 54		Node 76	
			Days[a]	f[b]	Days	f	Days	f	Days	f	Days	f
1	51.3	147	106	.72	39	.27	41	.28	73	.50	13	.09
2	51.1	120	92	.77	33	.27	37	.31	61	.51	10	.08
3	51.6	124	97	.78	40	.32	42	.34	72	.58	14	.11
4	51.8	146	107	.73	35	.24	38	.26	66	.45	4	.03
5	49.8	147	111	.76	41	.28	42	.29	74	.50	6	.04
6	52.2	128	95	.74	32	.25	37	.29	63	.49	14	.11
7	49.6	150	107	.71	33	.22	39	.26	67	.45	10	.07
8	51.0	126	99	.79	30	.24	37	.29	70	.56	15	.12
9	52.7	136	103	.76	37	.27	39	.29	69	.51	15	.11
10	49.8	126	94	.75	35	.28	39	.31	68	.54	7	.06
11	50.2	141	103	.73	35	.25	40	.28	75	.53	10	.07
Mean f			.748		.263		.290		.508		.080	
Standard deviation			.0236		.0277		.0255		.0419		.0310	
95% Confidence Limits												
Lower			.695		.201		.240		.415		.011	
Upper			.801		.325		.340		.601		.149	
Comment			Always Closed		Always Open		Always Open		Open or Closed		Always Open	

[a] Number of WPC days 70 MPN/100 mL.
[b] Days/WPC. If f 0.5, node is colsed to shellfishing.

Table C-4.0-2

EFFECT OF TOTAL RAINFALL ON MMM RESULTS

Annual Rain (in)	Load Reduction (%)	WPC	Number of WPC 70 MPN/100 ml				
			Node 11	Node 18	Node 41	Node 54	Node 76
51.3	0	147	147-C	138-C	147-C	147-C	147-C
51.3	95	147	106-C	39-O	41-O	73-O	13-O
45.9	0	138	138-C	130-C	137-C	138-C	138-C
45.9	95	138	96-C	33-O	34-O	64-O	13-O

C-Closed.
O-Open.

CHAPTER C-5.0

APPLICATION OF MMM

5.1 GENERATION OF A WET YEAR

Rather than running the model for an average rainfall year, a wet year should be chosen. In this manner, the load reduction from the streams can be determined to cover almost all conditions, not just average ones. The definition of a wet year is taken to be the total annual rainfall with a 10% probability of exceedance; that is, a greater annual rainfall will occur only once every 10 years. This is in keeping with the state policy for dry weather analysis, which uses one in 10-year low flows.

The U.S. Geological Survey has determined some rainfall statistics for Long Island (USGS 1969). They analyzed 15 years of island-wide data, which include NOAA and USGS stations. This resulted in a mean annual rainfall of 43.4 in., and distribution as follows:

PROBABILITY OF EXCEEDANCE (%)	TOTAL RAINFALL (in.)
1	57.4
25	48.0
50	44.2
75	40.4
99	31.6

If this is plotted on probability paper, the 10% level rainfall is about 51.5 in. This is the design rainfall to be analyzed.

As discussed in Section 3.2.2, the mean rainfall at the Upton gauge was 46.9 in., which is slightly higher than the mean as determined by the USGS. This was used only to incorporate the correct statistical distribution in the model, however. Since the USGS analysis is island-wide, there is no need to adjust the 10% level rainfall by the ratio of the two means.

The manner in which MMM generates a wet year is as follows. Generally, the duration and magnitude of storms do not increase during a wet year; rather, the storms simply occur more frequently. MMM reduces the average time between storms, generating more storms over the year, which causes a higher annual rainfall. The total inches as computed by the model are compared with the number we are looking for (51.5) to verify that a wet year has been simulated.

5.2 TYPES OF MODEL RUNS

There are generally two sources of urban runoff to the shoreline model nodes — overland and stream. Stream runoff is defined as runoff that drains into the freshwater streams and is then transported to the bays. Overland runoff is runoff that which drains directly to the bays or tidal portions of the streams, either overland or through storm sewers. This distinction is made because these two types of runoff may require substantially different control measures. Overland runoff control may consist of street sweeping, dog ordinances, leaching catch basins, or recharge basins. Stream runoff can be controlled by making better use of the existing ponds and stream corridors. By detaining the runoff for up to a day, the coliform levels can be reduced substantially through natural die-off.

A listing of the nodes and their respective overland/stream sources is shown in Table C-5.0-1. Model runs are done to determine the relative effect of each source of runoff.

The primary point of the model runs is to determine the reductions in the coliform load of runoff (by biological, physical, or chemical measures) needed to reopen the shellfish beds in the South Shore/Great South Bays. Since there is a high degree of mixing and flushing in the Nassau bays, it is almost impossible to obtain a set of site-specific reductions. Therefore, the Nassau streams and bays will be considered a global system, and a single number (load reduction) will be determined. For Suffolk, the opposite is true. There is not much interaction in the nearshore areas, so it is relatively easy to obtain site-specific reductions.

These load reductions are being determined to guide planners in locating control measures. Once a plan is determined, the effectiveness of the control measures (in terms of the exact fraction of runoff load reduced for each node) can be put into MMM to show the actual number of shellfish beds that can be considered for reopening. The incorporation of site-specific control measures and reductions are presented in Chapter 7.0.

All shellfish bed openings and closings will be presented based on the 70 MPN/100 ml criterion, as this is generally more restrictive than the 230 MPN/100 ml criterion. If the 230 MPN/100 ml is violated and the 70 MPN/100 ml is not, this will be specifically mentioned.

Table C-5.0-1

RUNOFF DISTRIBUTION BY MODEL NODE

Node No.	Total Drainage (acres)	Overland Drainage (acres)	Overland Drainage (percent)	Stream Drainage (acres)	Stream Drainage (percent)
2	1623	1623	100	0	0
3	318	318	100	0	0
4	367	367	100	0	0
5	227	227	100	0	0
6	656	656	100	0	0
8	1298	1298	100	0	0
9	139	139	100	0	0
10	263	263	100	0	0
11	10963	3271	30	7692	70
13	441	441	100	0	0
14	752	752	100	0	0
16	703	703	100	0	0
17	2910	1525	52	1385	48
18	4040	1045	26	2995	74
19	2980	1614	54	1366	46
21	8619	1751	20	6868	80
23	3168	1410	45	1758	55
24	402	402	100	0	0
26	465	465	100	0	0
40	3407	871	26	2536	74
41	4312	601	14	3711	86
51	3215	756	24	2459	76
52	1605	555	35	1050	65
53	2339	854	37	1485	63
54	8165	922	11	7243	89
55	3688	613	17	3075	83
56	676	247	37	429	63
76	5723	1129	20	4594	80
77	2277	744	33	1533	67
79	1447	77	5	1370	95
82	1647	440	27	1270	73
84	2549	893	35	1656	65
85	359	330	92	29	8
87	258	123	48	135	52
89	1359	765	56	594	44
Total	83360	28190	34	55170	66

5.3 MODEL RESULTS

The first set of runs done was for equal reduction everywhere. All nodes were analyzed for the present (no reduction) loads, and those that were deemed closed by the model were run for reductions from 50% to 100%. The nodes that are in real life closed to shellfishing, but predicted open by the model, are 26, 34, 85, 87, and 89. Nodes 26 and 34 will respond more quickly to load reductions than those closer to shore, so these can be ignored. Nodes 85 and 87 consists of small, closed areas fed by small creeks, and as such are poorly reproduced by the model. Load reductions similar to those determined for other areas should suffice for these nodes. Node 89, Carmans River, is a definite paradox. The land usage and model both show that the area should be open, but actual data say otherwise. An undetermined source may be contributing to the problem.

The remaining nodes (totaling 15,647 acres of closed beds) were analyzed for numerous reductions, and their responses (in terms of WPC greater than 70 MPN/100 ml) are shown in Figures C-5.0-1 through C-5.0-9. An overall view of the response of the bays is given in Table C-5.0-2, which shows the increase in shellfish bed openings as a result of decreasing loads. It must be remembered, however, that the open acres are node-dependent, and can be biased because of the model geometry. This simply means that the nodes are not all of equal size, and that a node that is barely reopened may not have been if it were slightly smaller. Hence, at smaller load reductions, the shellfish acres that are shown as opened may have only one or two nodes opened.

Table C-5.0-2

COLIFORM LOAD REDUCTIONS AND SHELLFISH BED OPENINGS AS PREDICTED BY MMM

Runoff Load Reduction (%)[a]	Opened Shellfish Beds: Nassau acres	Nassau %	Suffolk acres	Suffolk %	Total acres	Total %
0	0	0	0	0	0	0
50	2800	27	0	0	2800	18
75	4018	39	740	14	4758	30
85	5236	51	20007	37	7243	46
95	10195	99	4236	79	14431	92
99	10287	100	4690	88	14977	96
34[b]	3078	30	0	0	3078	20
66[c]	1812	18	740	14	2552	16

[a] Equal reduction of overland and stream runoff load.

[b] No overland runoff. 40% reduction in Nassau, 24% in Suffolk.

[c] No stream runoff. 60% reduction in Nassau, 76% in Suffolk.

It appears that an overall 95% reduction in coliform loads will reopen most of the shellfish beds. The farshore nodes (Figures C-5.0-1 to C-5.0-3) reopen at a lower level (50% to 75%) than the nearshore nodes (Figures C-5.0-4 to C-5.0-7) in Nassau. The Suffolk nodes (Figures C-5.0-8 and C-5.0-9) reopen at levels of 75% to 99% reduction. The two marginal areas are Node 11 (Mill Creek) and Node 53. Mill Creek has a very high coliform load because of the large drainage area. Node 53 has a very high background concentration (Table C-2.0-1) in the streams. If it is assumed that cleanup and control measures will also improve natural conditions, then there should be no problem in this node.

The next two model runs done were to see the effects of overland and stream loads. In Nassau (up to Node 51), 40% of the drainage is overland, while only 24% is overland in Suffolk (see Table C-5.0-1), with an overall fraction of 34%. The responses are shown in Table C-5.0-2. In Nassau, a 34% reduction (removal of all overland loads) opens 3078 acres, while a 66% reduction (removal of all stream loads) opens only 1812 acres. This is because the westernmost and farshore nodes receive only overland runoff, while the remaining nearshore nodes receive both overland and stream runoff.

The last model run done was to determine a design storm. The previous runs had controls on all runoff; the question remained as to what the maximum storm was that needed to be controlled (see Section 3.3.2). A series of runs was done using design storms from 0.3 to 2.0 in. and overall load reductions of 95%. Using the existing NYSDEC criteria, the model shows that controlling storms up to 1.25 in. gives the same results (in terms of shellfish bed openings) as controlling all storms at a 95% load reduction. So this can be considered a design storm, although it need not be. If the annual loading to the bays is reduced by 95%, regardless of storm size, the model predicts that at least 90% of the now closed shellfish beds can be opened (Table C-5.0-2).

As a possible planning option, if one disregards the 10% -2 30 MPN/100 ml NYSDEC criterion, and regulates shellfish closings solely on the 70 MPN/100 ml restriction, at a load removal of 95% the model predicts the same bed openings with a design storm of about 0.6 in.

REFERENCES CITED

HydroQual. 1981. Nassau County, *New York streamflow augmentation study.* Appendix H, Marine studies. May 1981.

Mitchell, R., and C. Chamberlin. 1978. Survival of indicator organisms. *In* G. Berg (ed.), *Indicators of viruses in water and food.* Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

Nassau County Department of Health [NCDH]. 1976. *Nassau County water quality assessment report.* Appendix IA, Surface water bacteriological data, 1976 report year.

Redman, J.H. 1979. *Accumulation and elimination of coliform bacteria by hard clams* (Mercenaria mercenaria) *in Great South Bay (Babylon Cove vicinity) during the summer and fall, 1978.* February 1979.

Redman, J.H. 1981. Personal communication re methods used for closure of shellfish beds.

Tetra Tech. 1977a. *Water quality modeling,* Hempstead Bay, Middle Bay, East Bay, South Oyster Bay, Great South Bay, Long Island, New York. Prepared for Nassau-Suffolk Regional Planning Board. November 1977.

Tetra Tech. 1977b. *Documentation report for the estuary water quality models.* Prepared for Nassau-Suffolk Regional Planning Board. May 1977.

Tetra Tech. 1978. *User's guide for the estuary water quality models.* Prepared for Nassau-Suffolk Regional Planning Board. January 1978.

U.S. Environmental Protection Agency (EPA). 1979. *A statistical method for the assessment of urban stormwater.* EPA 440/3-79-C23 [NTIS PB-299-185].

U.S. Geological Survey (USGS). 1969. *The precipitation regime of Long Island, New York.* Geological Survey Professional Paper 627-A.

Weston. 1977. *Wet weather runoff pollutant loads in Nassau and Suffolk counties.* April 1977.

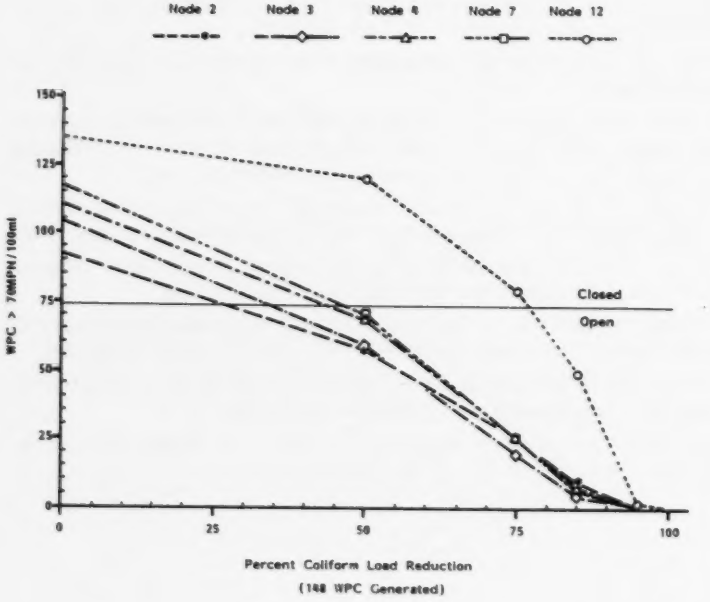


FIGURE C-5.0-1 *MMM results for overall load reductions, far-shore Nodes 2 to 12*

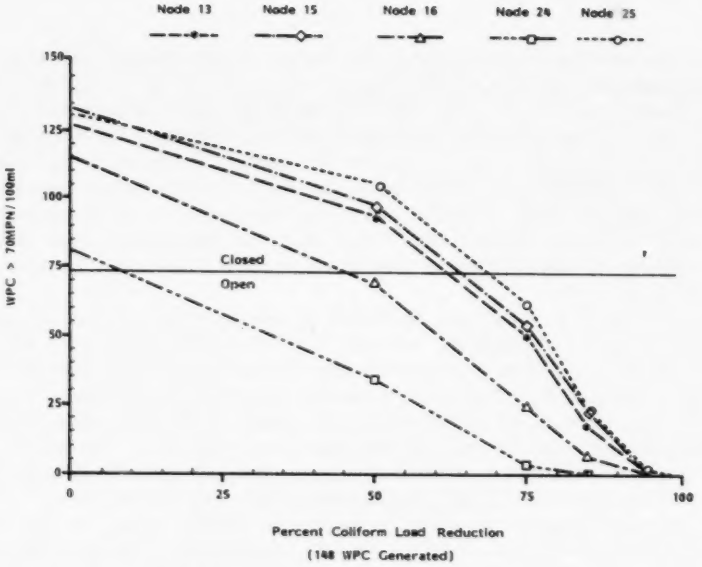


FIGURE C-5.0-2 *MMM results for overal load reductions, far-shore Nodes 13 to 25*

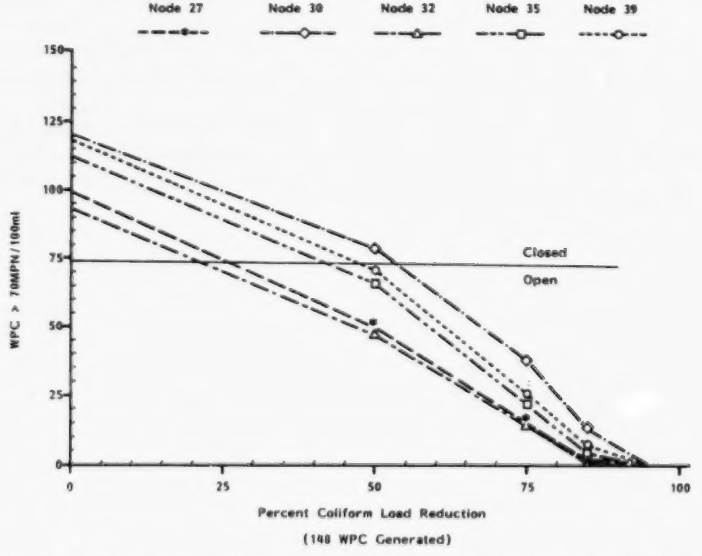


FIGURE C-5.0-3 *MMM results for overall load reductions, far-shore Nodes 27 to 39*

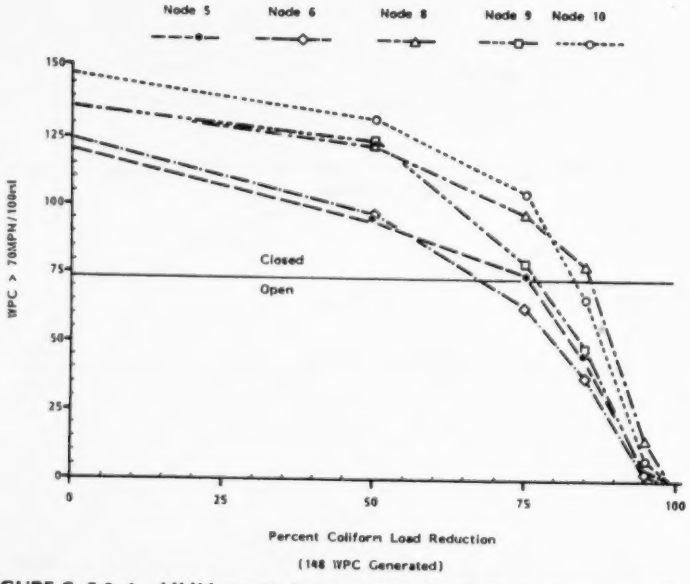


FIGURE C-5.0-4 *MMM results for overall load reductions, near-shore Nodes 5 to 10*

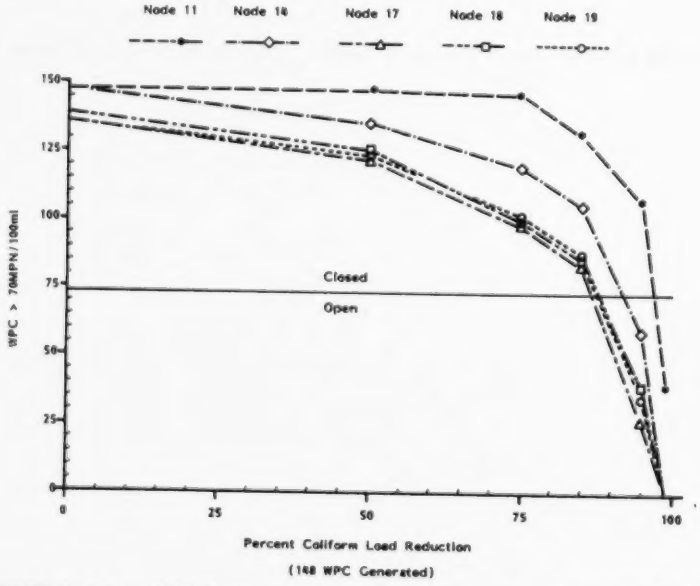


FIGURE C-5.0-5 *MMM results for overall reductions, near-shore Nodes 11 to19*

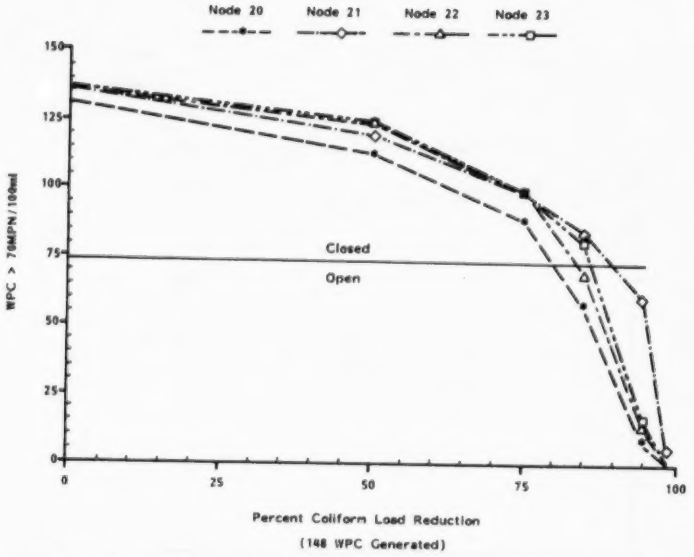


FIGURE C-5.0-6 *MMM results for overall load reductions, near-shore Nodes 20 to 23*

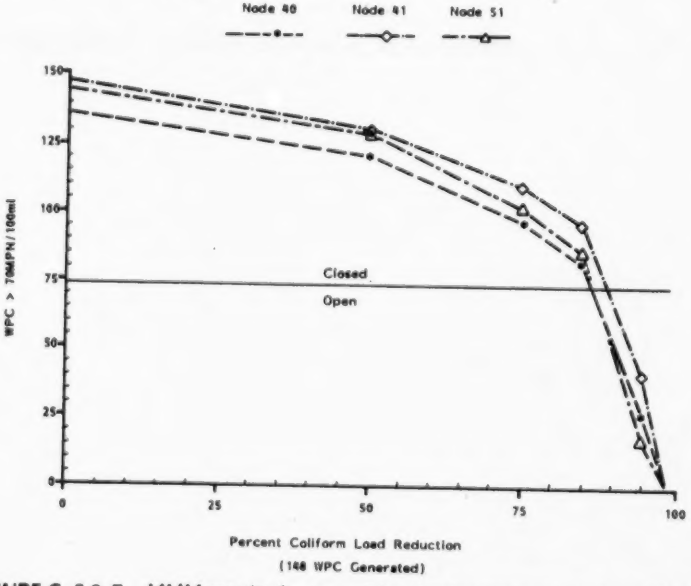


FIGURE C-5.0-7 *MMM results for overall load reductions, near-shore Nodes 40 to 51*

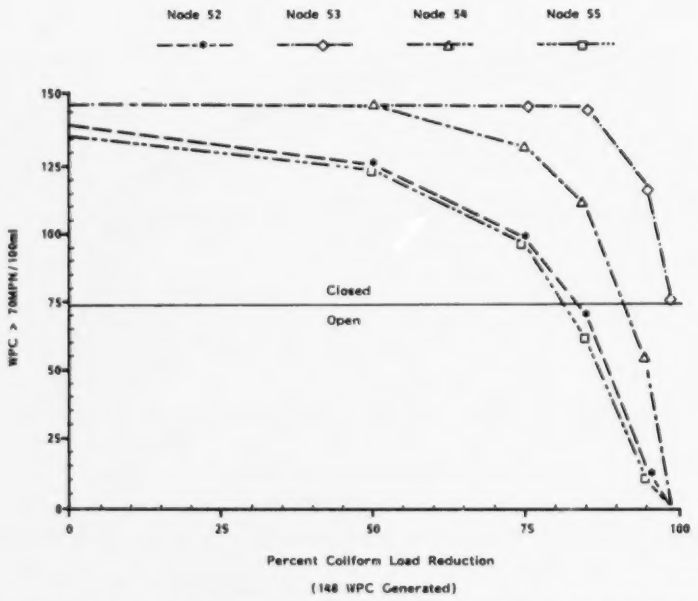


FIGURE C-5.0-8 *MMM results for overall load reductions, Suffolk Nodes 52 to 55*

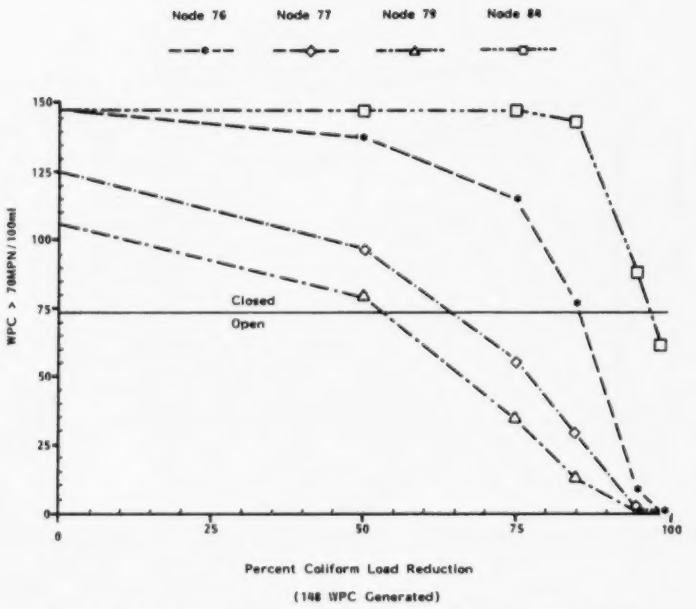


FIGURE C-5.0-9 *MMM results for overall load reductions, Suffolk Nodes 76 to 84*

Appendix G

Calculation of the Value of the Standing Crop of Hard Clams Found in Uncertified Portions of Selected Nodes in Suffolk County

CALCULATION OF THE VALUE OF THE STANDING CROP OF HARD CLAMS FOUND IN UNCERTIFIED PORTIONS OF SELECTED NODES IN SUFFOLK COUNTY

There are clearly many benefits involved with the improvement of water quality that can be achieved through implementation of the various structural and non-structural alternatives for the control of urban run-off. Attachment **A** describes some of these benefits, which are, however, often very difficult to quantify in economic terms. They are, nevertheless, extremely important and should be considered in any cost-benefit analysis of the pollution conrol alternatives.

Without quantitative information on all of these benefits, the only recourse was to conduct an analysis of the standing stock of hard clams found in the various nodes* subject to water quality improvement through the implementation of various alternatives. This analysis was limited by the extent to which data on hard clam standing stocks were available. Consequently, only four nodes were analyzed, none of them in the Nassau County south shore bay system.

The procedures utilized to calculate the current value of the standing stock of hard clams in the uncertified portion of several nodes are described in Attachment **B**. The results of the analysis are shown in Table G-1 . Briefly, the number of seed clams, littlenecks, and cherrystones/chowders was calculated for the uncertified portion of each node for which shellfish density data were available. Ranges in the yearly wholesale market price of hard clams, supplied by New York Sea Grant Extension Service, were used to calculate a range in value for the standing stock of clams in each size class. The price ranges for the size classes are listed below:

— Little necks: 13¢ to 18¢ per clam.
— Cherrystones/chowders: 4¢ to 12¢ per clam.

Although the commercial sale of seed clams (those less than 1" in thickness) is illegal, it is common knowledge that a black market does exist for clams of this size. Rather than try to estimate a percent of the seed standing stock that survives and is recruited into the commercial fishery in a given year, which is problematical because of uncertainty in understanding the hard clam density-mortality function, it was decided to calculate the value of the seed standing stock using a price range of 14¢ to 18¢ per clam.

*"**Nodes**". A term used in the mathematical modeling of the bays. The bay areas were divided up into a number of hypothetical individual water bodies, called nodes. These were numbered for identification.

The results of this analysis are listed in Table G-1. They are highly constrained by the format of the available data on shellfish standing stock and the problem of assigning a numerical value to the future production of shellfish in these areas. The numbers reflect only the conditions as inventoried in the year in which the data report was prepared (1978); no estimate of the potential value of future sets of hard clams in these areas could be made.

ATTACHMENT 'A'

Criteria for Assessing Benefits to be Realized from Water Quality Improvements in Areas Now Closed to Shellfishing

1. *Commercial Shellfishing Benefits.*

   Will opening an area that is currently closed result in greater shellfishing opportunity? The benefit to be realized will be dependent upon the standing crop of commercial shellfishing species in the subject area, and whether or not this area has been subject to illegal harvesting. Closed areas with high standing crops may provide an important source of brood stock that contributes clam larvae to the entire bay system. Reduction of these stocks through harvesting may impose a cost on the entire bay in terms of reduced shellfish recruitment.

2. *Ecosystem Benefits.*

   The reduction of non-point source pollutant loadings will result in improvement in water quality, not only with respect to the levels of coliform bacteria present, but also with respect to the levels of heavy metals, nutrients and organic chemicals. The removal or reduction of these pollutants should result in improved environmental conditions for desirable species at all trophic levels. The overall health of the bay ecosystem would be improved. Those activities dependent upon a healthy ecosystem — commercial fishing, recreational fishing, bird watching, hunting, etc. — all would enjoy the benefits of improved water quality. The partitioning of these benefits, however, is problematical.

3. *Aesthetic Benefits.*

   Reduction or elimination of stormwater runoff loadings will improve the aesthetic quality of surface waters in areas of restricted circulation. Recreational opportunities, eg., beach use and bathing, may be maintained or enhanced.

4. *Public Health Benefits.*

   There may be a certain incidence of illness associated with the ingestion of contaminated shellfish taken from uncertified areas. This incidence may decrease as a result of water quality improvement. In addition to the loss of work, inconvenience, and health-related expense associated with such illness, the bad publicity that could result from a serious health problem directly related to shellfish poisoning would be avoided. This provides a benefit for general public health, as well as a benefit to the shellfish industry.

ATTACHMENT 'B'

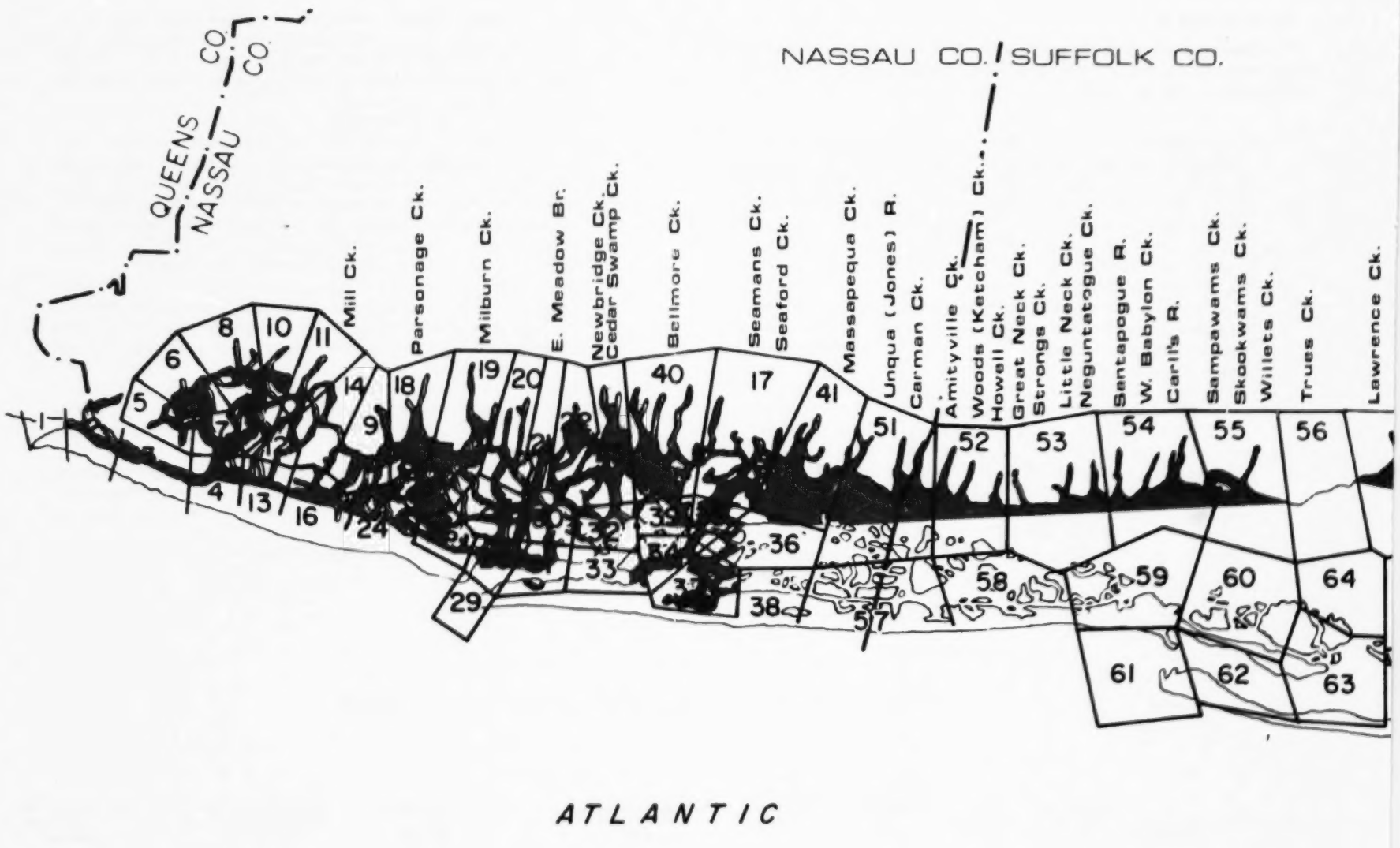
Procedure for estimating the values of shellfish (hard clams) in uncertified areas of selected nodes in south shore waters on Long Island. (Nodes were selected by availability of data.)

1. Given the water area per node and the percentage of nodes designated uncertified, calculate the uncertified water area per node.
2. Transfer the boundaries of nodes and of uncertified areas from Fig. C-2-0-1, *Model Segmentation and Uncertified Shellfish Areas*, Lawler, Matusky and Skelly, 1982 to shellfish distribution maps (Figs. 2-3, 2-4, and 2-5 from U.S.E.P.A., *Draft Report 1982 — Impact Assesment on Shellfish Resources of Great South Bay, South Oyster Bay, and Hempstead Bay, New York.* In preparation.)
3. Make transparencies of the shellfish distribution maps (with the added boundaries), project them with an overhead projector, and count the number of stipples within each density category within each node. All stipple points are laid out in a square grid. The grid width is the same for all density categories, only the point size varies. Starting with Fig. 2-3, *Distribution and Abundance of Mercenaria Mercenaria*, count the number of points within each density category, and sum to get the total number of clams larger than seed size for each node. Then calculate the percentages of all density categories within each node. The density category is determined by the average of two successive contour values. For example, the region between contour lines 100 and 200 is considered to have a density of 150 clams per unit area; between 25 and 50, a density of 37.5, etc. (Notes: Numbers designating contour lines obliterate stippling. Therefore, counts of points have to be estimated in some places. Also, boundary lines have to be estimated. A small portion of node 77 includes *leased grounds* for which no shellfish distribution data were collected; however, the area of the entire node was considered in calculations.)
4. Transform densities to clams/M^2.
5. Using information from Fig. 2-4, *Size Composition of Hard Clam Population*, calculate the percentage of each density category per node that contains clams greater than 70mm shell length (cherrystone and chowders). Multiply the number of clams per density category by the corresponding percentage for that region to find the number of clams per density category that are cherrystones/chowders. (Note: In data collection, cherrystones and chowders were pooled.)
6. Subtract the number of cherrystones/chowders for a given density category from the total number in that category, in order to determine the number of littlenecks (size range from greater than 48mm to less than 70mm shell length) in a given density category in a selected node. Do this for all nodes.
7. Sum the abundances in all density categories for each node.
8. Calculate the number of seed clams per node, using Fig. 2-5, *Distribution and Abundance of Seed Clams (Tongs)* and employing the above procedure.
9. Given the wholesale price range of clams of different size categories ($/clam), multiply the abundance of clams of a given size category per node by the lowest and highest prices per clam to obtain a price range for a given size category per node.
10. Tabulate the results of the analysis. (Table G-1).

Table G-1

VALUES OF SHELLFISH IN UNCERTIFIED AREAS OF SELECTED NODES IN SUFFOLK COUNTY

Node #	Water Area (millions M^2)	% Node Uncertified	Uncertified Water Area M^2	# seed clams/node (uncert.)	# Littlenecks per node (uncert.)	Cherrystones and chowders per node (uncert.)	Value of seed clams per node (uncertified)		Value of Littlenecks per node (uncertified)		Value of Cherrystones and Chowders per node (uncertified)		Total value of all clams per node (uncertified)	
52	4,836	32	1,547,520	667,075	730,773	6,576,960	$ 93,391	120,074	95,000	131,539	$263,078	789,235	$ 451,469	1,040,848
55	7,347	46	3,379,620	13,057,623	23,122,234	7,763,738	1,828,067	2,350,372	3,005,890	4,162,002	310,550	310,550	5,144,507	7,444,023
76	11,439	36	4,118,040	9,424,696	47,159,202	7,366,698	1,319,457	1,696,445	6,130,696	8,488,656	294,668	884,004	7,744,821	11,069,105
77	10,137	14	1,419,180	2,515,819	22,851,426	11,629,392	352,215	452,847	2,970,685	4,113,257	465,176	1,395,527	3,788,076	5,961,631


QUEENS CO.
NASSAU CO.
NASSAU CO. / SUFFOLK CO.
Mill Ck.
Parsonage Ck.
Milburn Ck.
E. Meadow Br.
Newbridge Ck.
Cedar Swamp Ck.
Ballmore Ck.
Seamans Ck.
Seaford Ck.
Massapequa Ck.
Unqua (Jones) R.
Carman Ck.
Amityville Ck.
Woods (Ketcham) Ck.
Howell Ck.
Great Neck Ck.
Strongs Ck.
Little Neck Ck.
Neguntatogue Ck.
Santapogue R.
W. Babylon Ck.
Carll's R.
Sampawams Ck.
Skookwams Ck.
Willets Ck.
Trues Ck.
Lawrence Ck.
1
4
5
6
7
8
9
10
11
13
14
16
17
18
19
20
24
29
32
33
34
35
36
38
40
41
51
52
53
54
55
56
57
58
59
60
61
62
63
64
ATLANTIC

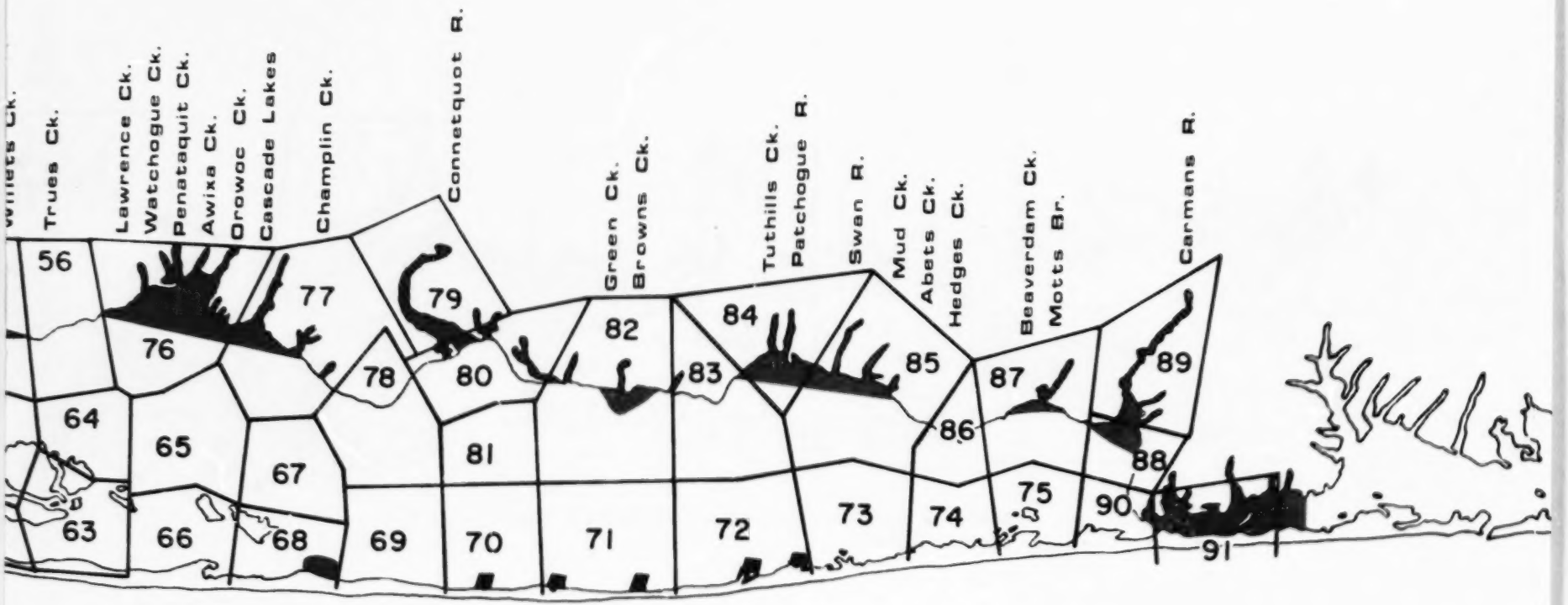
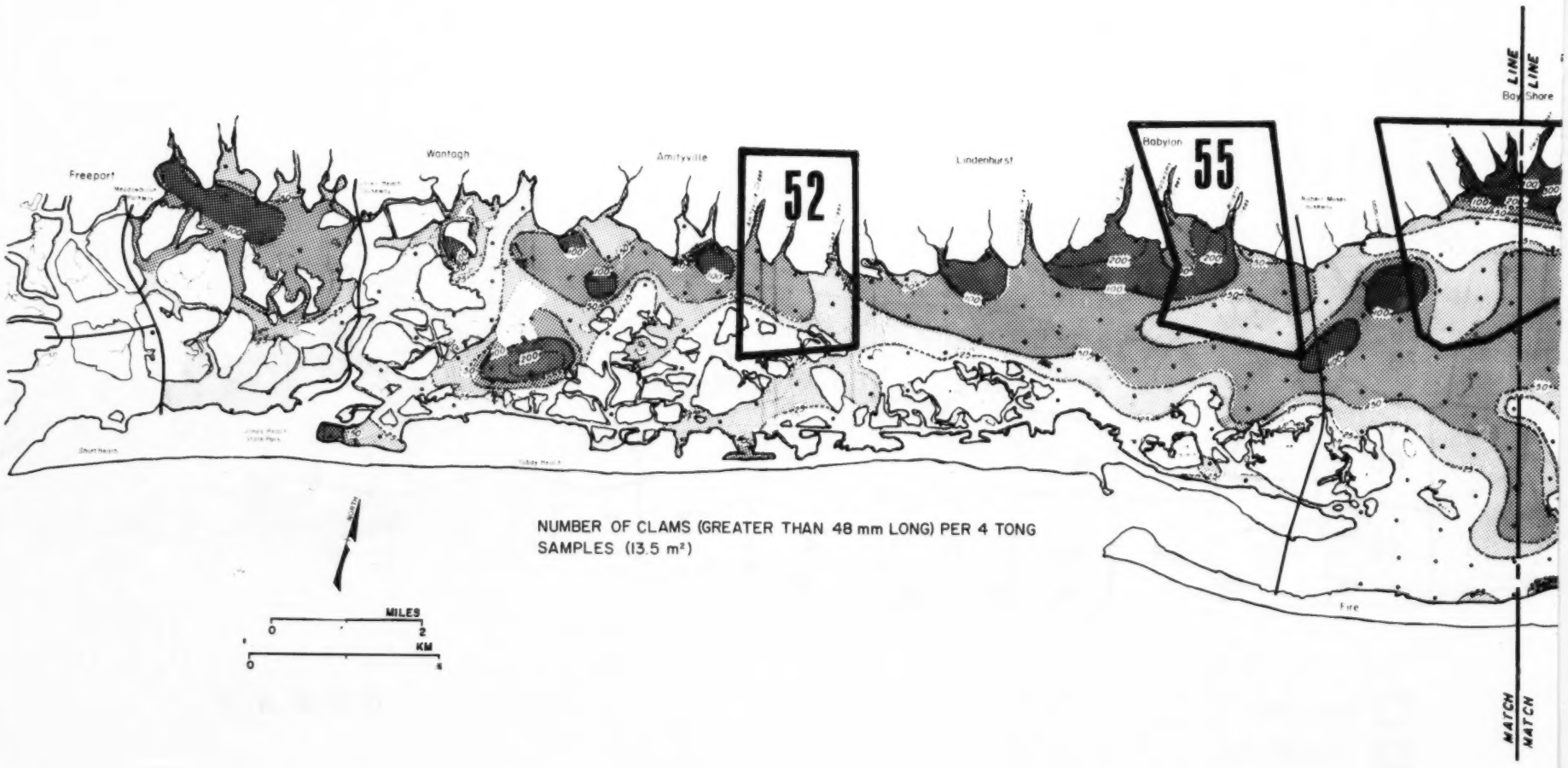


FIGURE C-2-0-1 *Model segmentation and uncertified shellfish areas (Lawler, Matusky and Skelly, 1982)*


Freeport
Wantagh
Amityville
Lindenhurst
Babylon
52
55
LINE
LINE
Bay Shore
MATCH
MATCH
NUMBER OF CLAMS (GREATER THAN 48 mm LONG) PER 4 TONG SAMPLES (13.5 m²)
MILES
0
2
KM
0

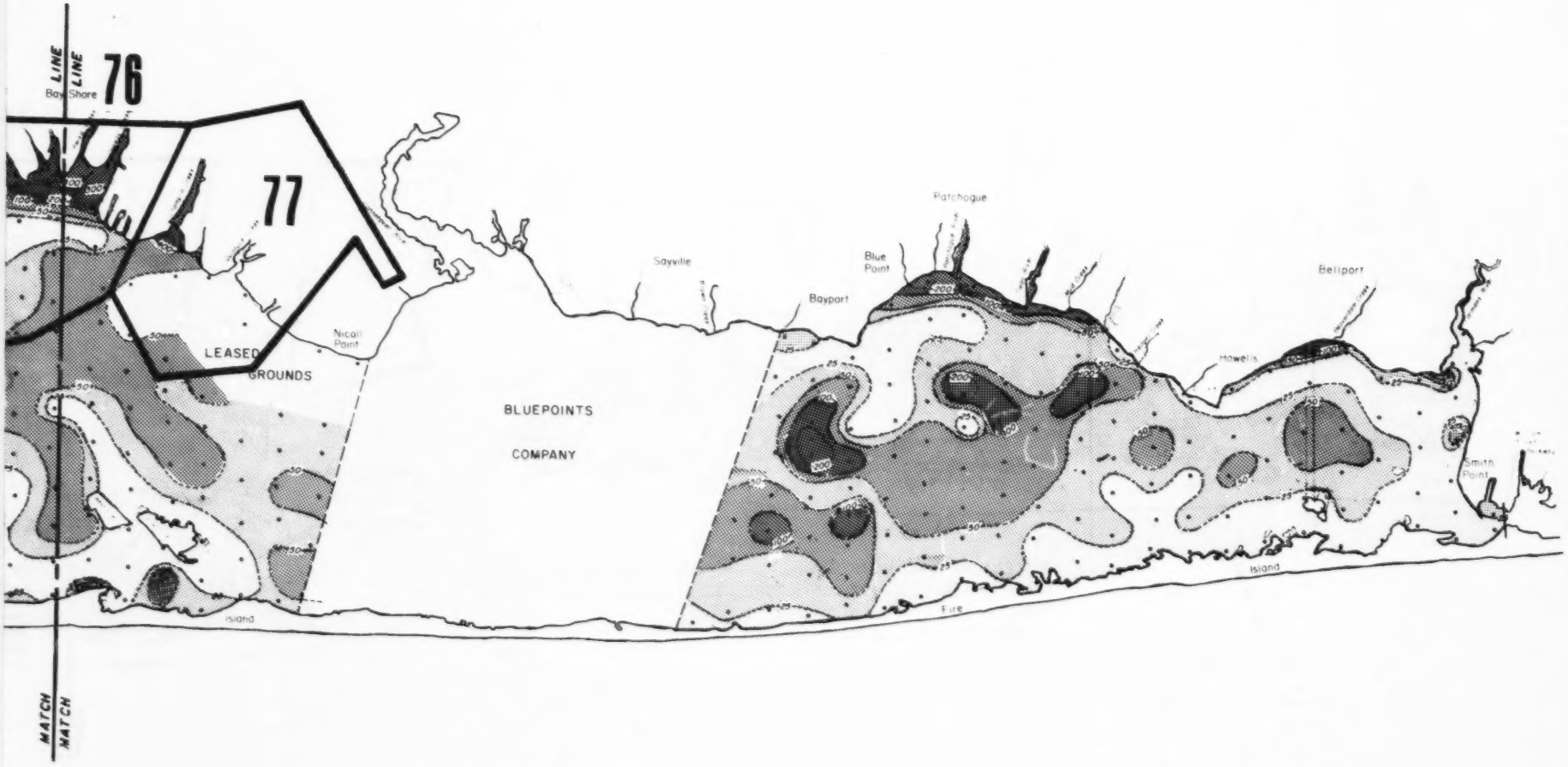
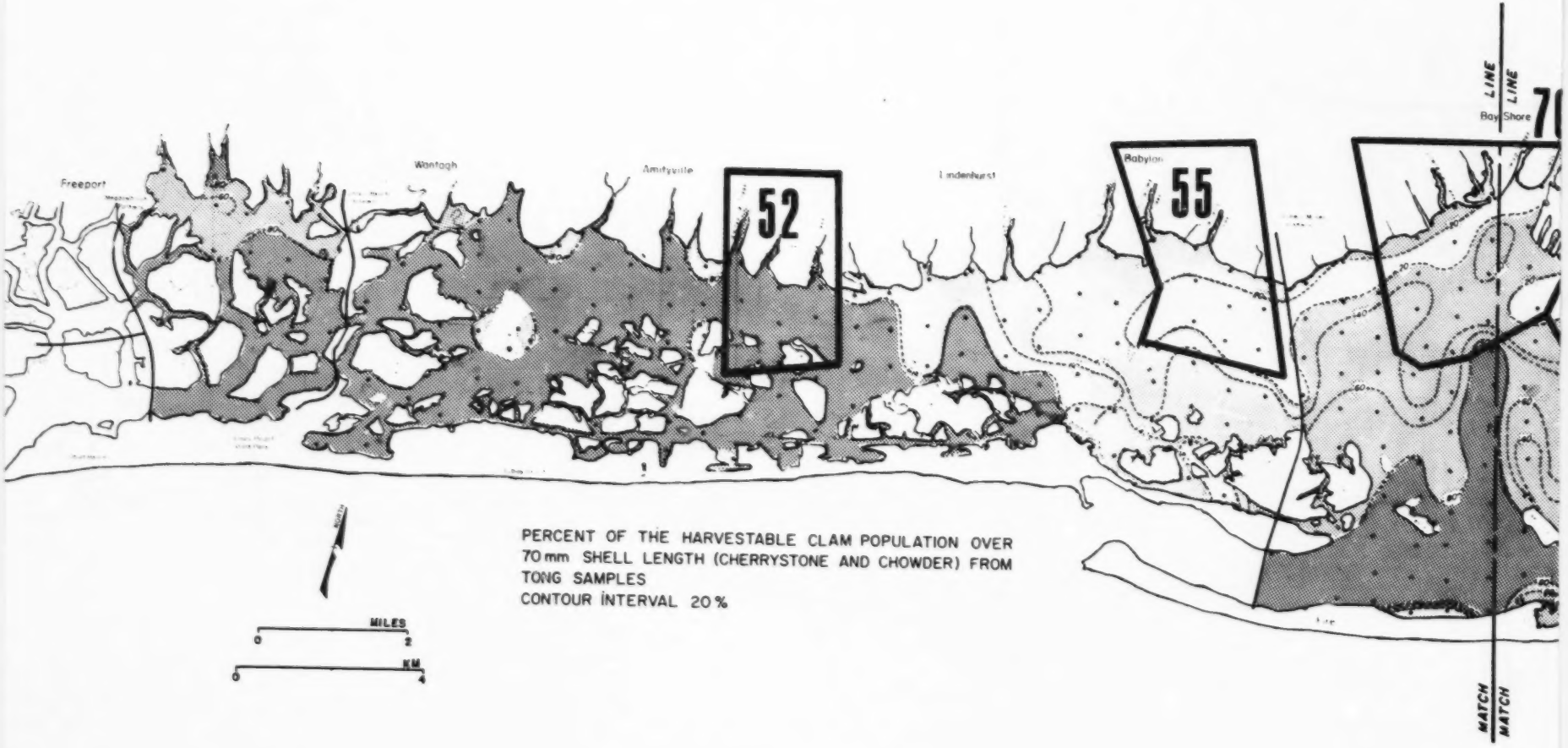


FIGURE 2-3 *Distribution and abundance of Mercenaria Mercenaria (U.S.E.P.A. Draft Report, 1982)*



PERCENT OF THE HARVESTABLE CLAM POPULATION OVER 70 mm SHELL LENGTH (CHERRYSTONE AND CHOWDER) FROM TONG SAMPLES
CONTOUR INTERVAL 20 %

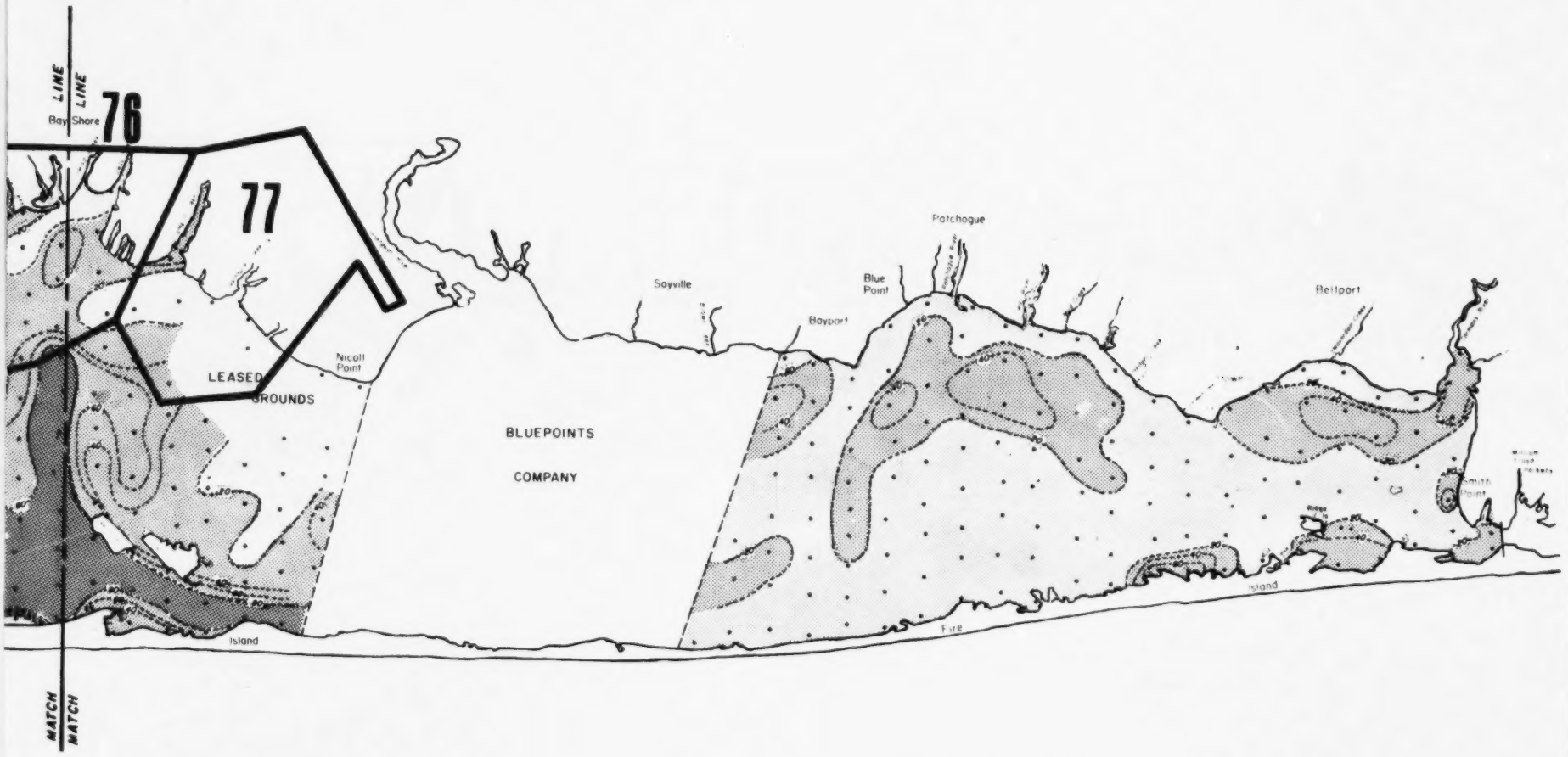
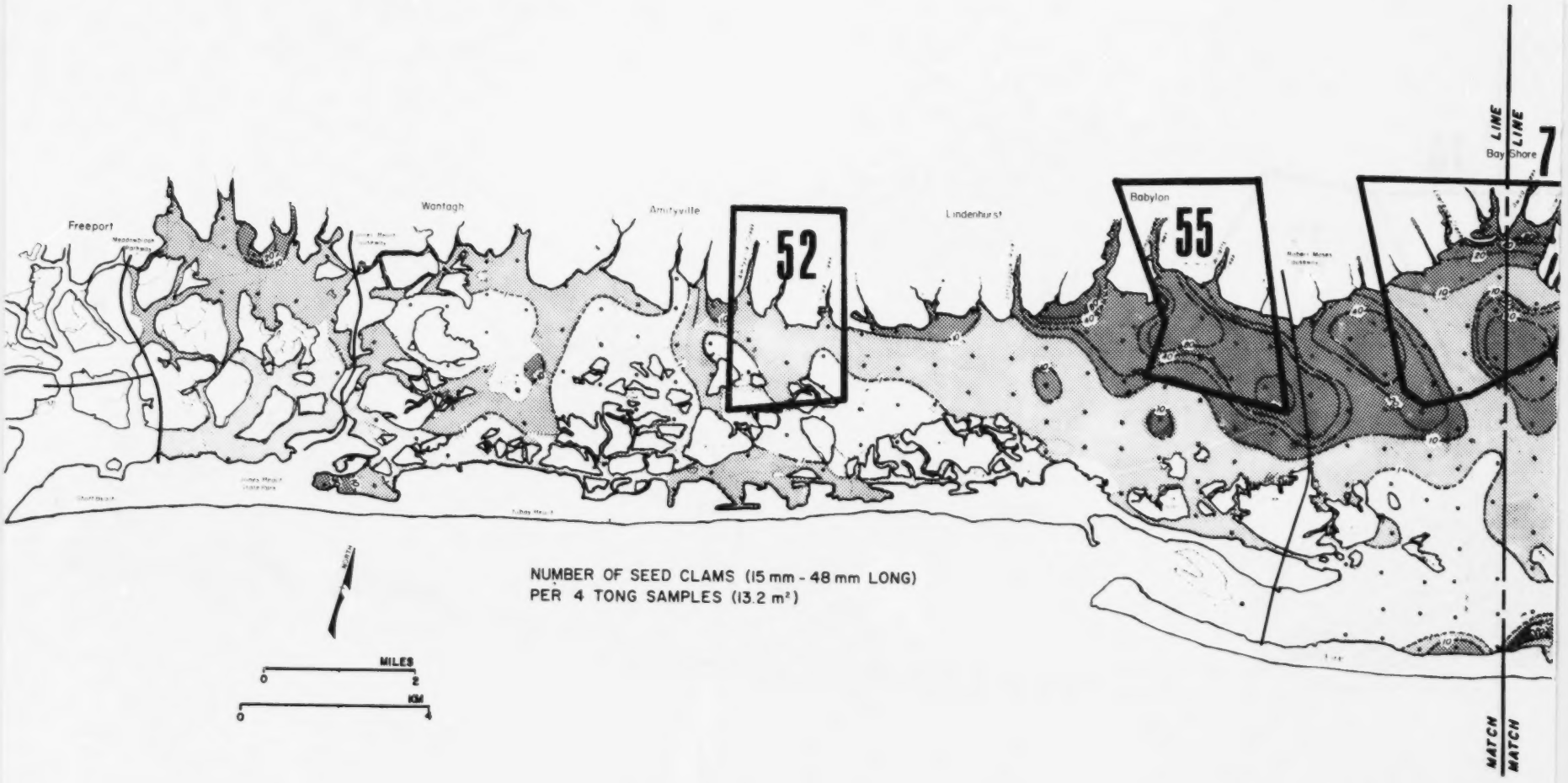


FIGURE 2-4 *Size composition of Hard Clam populations (U.S.E.P.A. Draft Report, 1982)*


Freeport
Wantagh
Amityville
Lindenhurst
Babylon
Bay Shore
52
55
7
LINE
LINE
MATCH
MATCH
NUMBER OF SEED CLAMS (15 mm - 48 mm LONG)
PER 4 TONG SAMPLES (13.2 m²)
MILES
0
2
KM
0
4

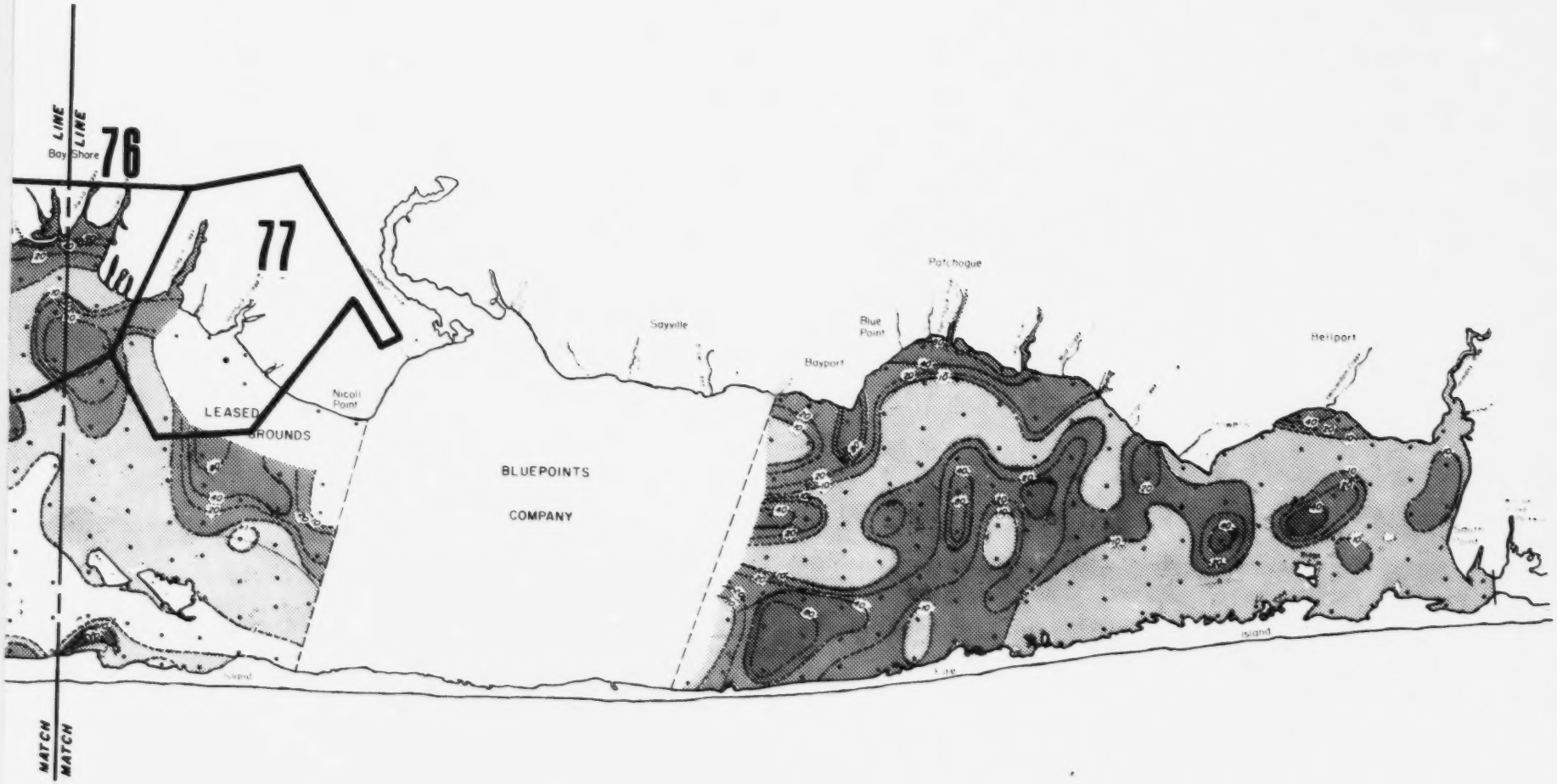


FIGURE 2-5 *Distribution and abundance of Seed Clams (Tongs) (U.S.E.P.A. Draft Report, 1982)*

Appendix H

Salmonella Study—Progress Reports

Preceding page blank

Agency—Nassau County Department of Health
Nationwide Urban Runoff Program
Salmonella Project Report
May 1981 - Febrauary 1982

May to October

Our original plan for start-up of the project included four steps: 1) interviewing and hiring of technical personnel; 2) preparation of laboratory space; 3) purchase of equipment and supplies and 4) training of technical personnel. Four months were allotted to this early phase. Approval of the project was received in May, with another month required for issuance of a purchase order number to begin assembling supplies and equipment. After our orders were placed they had to follow routine channels, as project funds were placed into the general County fund, resulting in our not receiving all of our necessary equipment and supplies until October. Interviewing personnel and the lengthy hiring process took from June to October, with the full complement of three technical personnel finally in place late in October. Thus between May and October we had completed the first three steps of the start-up phase.

October to present

The first two weeks were devoted to assembling equipment, storing supplies, stabilizing water baths, sterilizing Millipore equipment and supplies, and generally organizing the laboratory.

Step 4 of the start-up phase was compressed into these early weeks and included having all three people spend time in the Clinical Microbiology section of the laboratory, gaining experience in enteric bacteriology. Record keeping and quality control procedures were also set up.

By early November we had experience in media preparation, control of stock cultures, sterility check procedures, plate counting, Millipore filtration techniques and MPN determinations.

A common problem in biological research is the reproduction of techniques reported in the literature. We had planned to follow the procedures of Kenner and Clark, but quickly determined that there were several aspects of their study that did not work in our hands. The DSE broth for Salmonella MPN determination required heating at 88 degrees C to sterilize it, with addition of an 18 hr. *S. paratyphii A* culture, also sterilized and autolyzed at 88 degrees C, to a volume of 10%. The difficulties we began to experience with contamination and breakdown of components of the media required several weeks to clarify. We also had to search the literature for background information on the DSE broth and its components. Experiments were run that clarified which components of DSE broth could be autoclaved together, the fact that the DSE functioned well without the *S. paratyphii A* and how the heat reduction of sodium acid selenite resulting in a red precipitate could be eliminated. We also determined DSE brother's selectivity using cultures of *Proteus vulgaris, Escherichia coli, Pseudomonas aeruginosa* and *Salmonella tyuphimurium*. We currently produce a clear, selective media sterilized by autoclave.

Our first MPN determinations using GF/F filters gave us the surprising result of sterile DSE broth tubes in the first row which contained the filter, and growth in the second row inoculated with broth from the first. Experiments were devised and run to show that the GF/F filters were bacteriocidal for Salmonella. We then proceeded to extraction studies and atomic absorption spectrophotometric analysis which demonstrated BA + +, Zn + +, and Fe + + +, in ppm quantities. Since the GF/F filters were such an integral part of our experimental plans we devoted time and effort to determine whether extended extraction with dilute nitric acid and slow exhaustive washing with deionized water would clear up the heavy metal contamination. Repeating the experiments of varying concentrations of Salmonella with and without GF/F filters indicated we could not solve the problem. Discussions with technical representative from Whatman Inc. who produce the GF/F filters indicated that their quality control extraction studies also demonstrated the oxides of barium, zinc and iron. A very recent conversation suggests that Kenner and Clark probably used as GF/F filter made from "E glass" which does not contain the impurities.

The problem we encounter with GF/F filters led us to try Millipore HA .45 type membrane filters for our MPN determinations. We ran a series of MPN studies with varying concentrations of *S. typhimurium* comparing them to direct plate counts. We also performed MPN's in triplicate to determine their reproducibility. We found some correlation at higher concentrations of bacteria but it became poorer at low concentrations, as did reproducibility.

In mid-December a series of experiments was begun to determine if Salmonella organisms could be released from Millipore membranes at different pH. The literature on virus concentration techniques describes how selective absorption is achieved at pH 3.5 and release or elution occurs at about pH 11. We found no release of Salmonella from Millipore membrane filters in DSE broth after vortexing. Solutions of .05 M glycine was prepared and adjusted to Ph 7, 8, 9, 10, and 11 using 10N NaOH. Five 100 ml quantities of a 10-5 dilution of Salmonella organisms were filtered and one Millipore membrane was placed at each pH in 10 ml of elution buffer. All tubes were vortexed, held for 15 minutes and then neutralized with pH 2 glycine. Maximum release occurred between pH 8 and 9 dropped off to very low values at pH 7 and pH 11.

When the experiments were rerun with GF/F filters maximum elution were also seen in the same pH range. Millipore and GF/F filters were then run in parallel, with elution at pH 8 using varying concentrations of Salmonella organisms. XLD spread plate counts in triplicate were made on elution buffer and on the suspension prior to filtration to determine efficiency. From the results in Figure 1 it can be seen that we had a good correlation between the number of organisms placed on the filter and those eluted at pH 8. At all dilutions the GF/F filters appeared to be more efficient in their percentage of release and at 10-8 they were able to pick up organisms not shown by Millipore filters or direct counts of the suspension.

In experiments to refine the elution procedure we examined the time required for maximum release of Salmonella organisms from the filter. A steady increase with time was found, which reached a maximum at 30 minutes and was essentially unchanged out to two hours. Elution experiments in the environmental literature utilize beef extract in concentrating viruses from sludge or membrane filters. We had Lab-Lemco broth available in the laboratory which consists of 3 parts beef extract to 5 parts peptone. When .05 M glycine buffer was compared to .05M glycine buffered 0. 8% Lab-Lemco broth we found that the latter enhanced the dilution effect at pH 8 with both Millipore and GF/F filters, and the GF/F continued to be almost twice as efficient as Millipore filters. By utilizing elution methods, counting bacteria in the eluate and then using it to inoculate 2x DSE broth we appear to have side-stepped the problem of filter toxicity.

In early January we began experiments using our optimized GF/F filter/elution system. The design involved seeding samples with varyng concentrations of *S. typhimurium* to simulate a storm event. All samples have been seeded in such a way as to make them unknowns to the technical people. Four complete experiments with four or more samples have been run. All four have shown a very good correlation with respect to the quantities of microorganisms seeded into the samples, as well as their efficiency of recovery. Figure 2 details the results of one such experiment which is particularly interesting because it brackets the lower limit of recovery by the filter/elution technique. The mean counts in the filter eluates follow the ratio of seeding of the samples fairly closely. Direct counts on the 25 ul and 2.5 ul sample could not be demonstrated. There were counts in the elution buffer for the 25 ul sample but not the 2.5 ul one. All eluates elicited growth in DSE broth. Calculations suggest 17 - 47 Salmonella organisms were enough to initiate growth in the DSE broth for sample 4, but not enough to be demonstrated by plate counts on eluate. We are attempting to reproduce this experiment at the lower limit of detection.

Our plans for the immediate future include experiments to study the survival of Salmonella at various temperatures. We hope to use this information to help guide us in handling storm event samples, Under controlled conditions in the laboratory we have developed the capability to accurately and efficiently qualify the presence of *Salmonella typhimurium* in seeded samples. We are now to the point where we would like to begin testing selected environmental samples to learn how the extra burden of debris and microorganisms effect our current GF/F filter/elution techniques.

	Organisms/100 ml Suspension to Filter	Organisms Eluted from Filter pH 8	% Released
10-4 Dil			
Millipore	1,375,000	525,000	100
GF/F	same	720,000	52
10-5 Dil			
Millipore	158,000	87,000	58
GF/F	same	116,300	74
10-6 Dil			
Millipore	31,500	21,900	70
GF/F	same	26,700	85
10-7 Dil			
Millipore	1,500	1,050	70
GF/F	same	1,30	87
10-8			
Millipore	0	0	0
GF/F	same	350	100

SIMULATED ENVIRONMENTAL SAMPLES
ORGANISM—*S. TYPHIMURIUM* 10-3 DIL OF 10 HR. CULTURE
FILGER—GF/F WITH 100 ML SAMPLE VOLUME
ELUTION .05 M GLYCINE BUFFERED .8% LAB-LEMCO BROTH pH 8 FOR 30' INOCULATED TO 2x DSE BROTH

Sample Number	Counts/100 ml Organisms on Filter*	Counts/10 ml Organisms in Elution Buffer	Replicate 2 Spread Plates in Triplicate	Replicate 3 Using 100 µl Samples	Mean of Replicates	Elution Efficiency	Growth in 2X DSE
1 Seeded 25 µl	0	130	100	233	154	100%	Yes
2 Seeded 100 ml	660	730	666	700	696	105%	Yes
3 Seeded 50 µl	660	466	400	400	422	64%	Yes
4 Seeded	0	0	0	0	0	—	Yes

*Spread plate counts on sample prior to filtration
0.1 ml samples in triplicate

Agency - Nassau County Department of Health
Salmonella Project Report
February through mid-October, 1982

In early February, three Salmonella samples were taken to begin application of the previously described GF/F filter/elution technique. Two were from the Oyster Bay STP, one of the influent and the other of prechlorinated effluent, with the third from Roslyn Pond. These first samples were to be a learning experience with respect to collection, transport, processing and microbial identification. A number of plates on all three specimens yielded characteristic black colonies which gave the impression we were dealing with Salmonella. More complete biochemical testing identified the organisms from the Roslyn Pond as *Citrobacter freudii*. Further examination of the Oyster Bay STP samples did not indicate the pressence of *Salmonella sp.*

The fact that we did no isolate Salmonella from the STP samples and that we experienced considerable overgrowth of other enteric bacteria caused us to compare DSE broth to other selective enrichment procedures. Vassiliadis et al (1981) reported on RV enrichment medium for meat samples which was formulated from tryptone, salts and malachite green. Several experiments were run comparing RV and DSE enrichment broths with respect to their ability to support the growth of quantitatively differeing inocula of *S. typhimurium* and *E. coli*, alone and in combination. DSE consistently outperformed the RV formulation.

Since the enrichment broth approach was not an improvement, we went back to the literature to see if there were any other types of separation procedures for Salmonella, at the very least, one that might favor Salmonella within a complex mixture of bacteria. In the *Journal of Applied Bacteriology* we found a short communication by Hall, Hogg and Phillips (1976) that described a DEAE-cellulose gradient elution technique for separating *S. typhimurium* from *E. coli*.

Their method utilized De-32 anion exchange cellulose in a large 2.5 cm. bore column with 0.05M phosphate buffer pH 6.0. A heavy 20 to 30 mg mixed suspension of bacterial cells in buffer was placed on the surface of the DEAE-cellulose and allowed to drain into the column. Elution was commenced by applying a linear gradient of NaC1 in buffer. Fractions (15 ml) were collected overnight, optical densities determined, and bacterial identifications performed based on the ability of *E. coli* to produce indole and ferment lactose, which *S. typhimurium* does not. The authors reported an *S. typhimurium* peak between 0 and 200 mM NaC1 separated from a following *E. coli peak*. We utilize their approach, modifying it to see if we could achieve separation in the elution step after GF/F filtration. Using Sigma DEAE-cellulose anion exchanger (medium mesh), washed in 0.05M glycine buffered Lablemco pH 6.0, we packed a 5cc volume into a cutoff 10 cc glass pipette. A mixture of *S. typhimurium* and *E. coli* was prepared to stimulate an environmental sample, filtered and the organisms eluted by our standard procedure. The GF/F eluate was placed on the column, followed by a 10 ml aliquot of pH 6 buffer to facilitate entry. A discontinuous gradient elution scheme followed, using pH 6 buffer with 100, 200, 300 and 400 mM NaC1 in 10 ml volumes. The five column eluates were counted by spread plate techniques with the results shown in Figure 1. As in the reference paper, *S. typhimurium* came off the column first in our discontinuous gradient elution system, followed by *E. coli*. The early Salmonella peak repeated for all subsequent experiments even though as the proportion of E. coli *in the mixture was increased if tended to swamp the S. typhimurium* by coming off in the earlier eluates. This column chromatographic approach to enteric bacteria separation is an academically interesting one, and would probably be very suitable as a graduate thesis project as there are at least six parameters* to study. We put it aside as the technique in its present form is tedius and the time involved makes it unsuitable for processing large numbers of environmental samples.

Prior to receipt of the first environmental sample in the laboratory we had run an experiment to determine the effect of temperature on the survival of *S. typhimurium*. A known dilution of bacteria was added to two liters of sterile distilled water, mixed, and then divided into two sample jugs with one held at 25 degrees C (room temperature) and the other at 4 degrees C (refrigerator temperature). At 24 hour intervals, plate counts were performed with the data

*Column size, type of DEAE, buffer ph, salt concentration, between concentration, bacterial type and numbers.

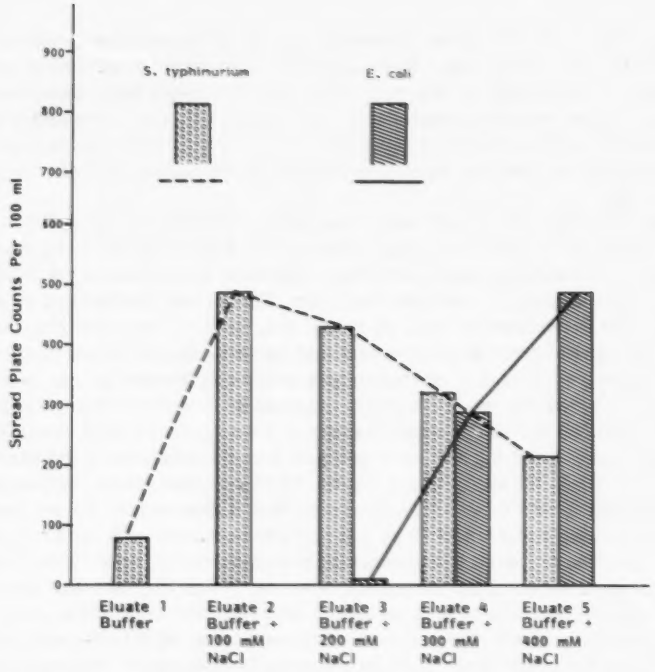


FIGURE 1 *DEAE—Cellulose Column Separation of S. typhimurium and E. Coli*

shown in Figure 2. Utilizing low levels of bacteria, there was a steady decline at room temperature with an approximate 90% die-off over the first four days. The *S. typhimurium* held at refrigerator temperature remained relatively stable over that same time period and had declined about 70% by the seventh day.

Repeat testing of the first three environmental samples in March again failed to grow out Salmonella. The two STP samples were routinely checked for pH and were found to be quite acidic at pH 4. This suggested that we repeat the survival experiments, expanding them to include pH and type of sample, as well as temperature. Figure 3 shows the results for *S. typhimurium* survival at three pH values and two temperatures. There was a very rapid die-off at pH 11, with complete inactivation at both temperatures even before the 0 hour sample could be plated. The pH 3 samples were also inactivated very rapidly and independent of temperature. At pH 7 there was a clear indication that decreased temperatures favors *S. typhimurium* survival. In Figure 4, the same experiment was repeated to include the intermediate pH 5 and pH 9 values with approximately twice the starting level of bacteria. The extreme pH values again caused rapid die-off, with the intermediate pH 5 and pH 9 values appear-

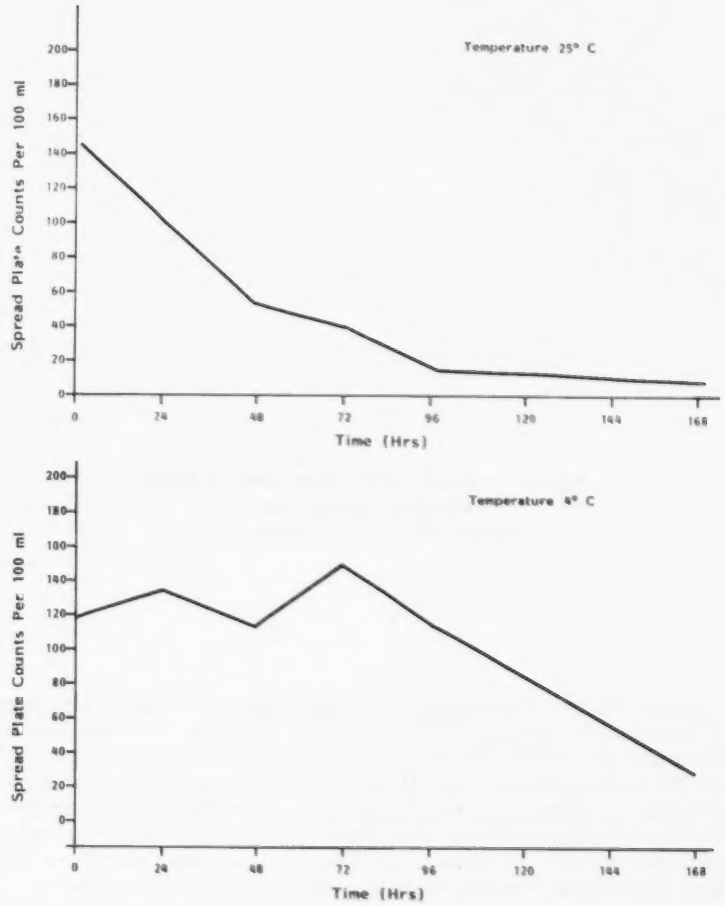


FIGURE 2 *Effect of Temperature on S. typhimurium in Distilled Water*

ing to parallel pH 7. Again, the 4 degree C temperature favored survival. This same type of experiment was run using buffered pond water, shown in Figure 6, with essentially the same results. In all three types of suspending medium, survival of *Salmonella typhimurium* was favored by cold and less extreme pH values. We intend to extend this area of investigation to include storm water runoff and sewage treatment plant influent with their heavy burden of suspended matter and bacterial flora.

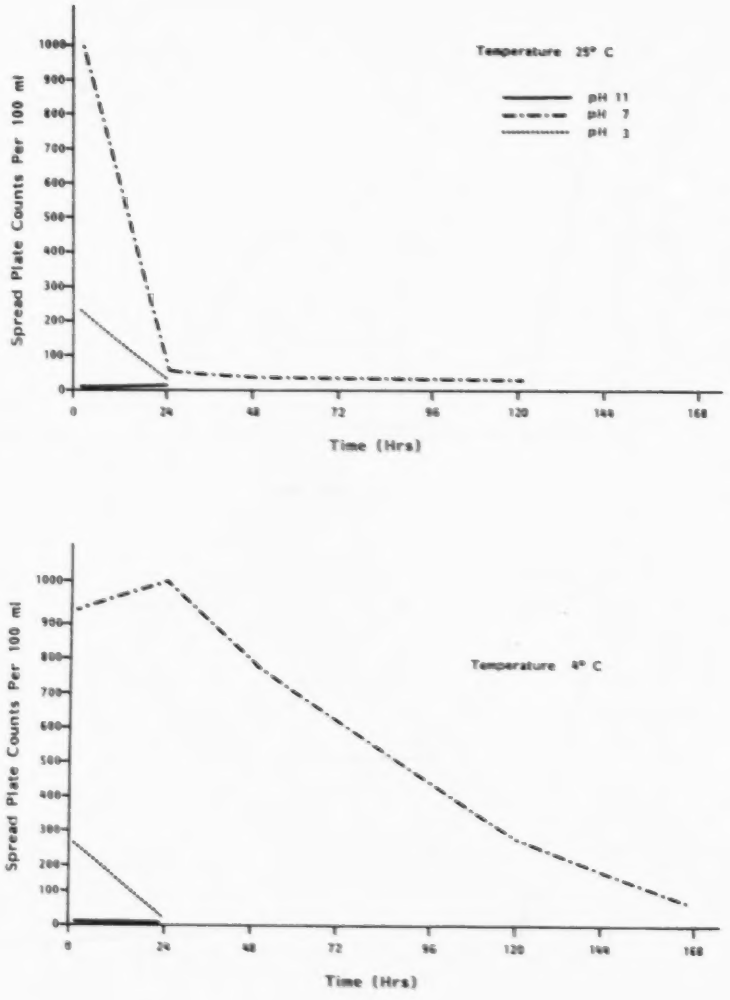


FIGURE 3 *Effect of Temperature and pH on S. typhimurium in Buffered Distilled Water*

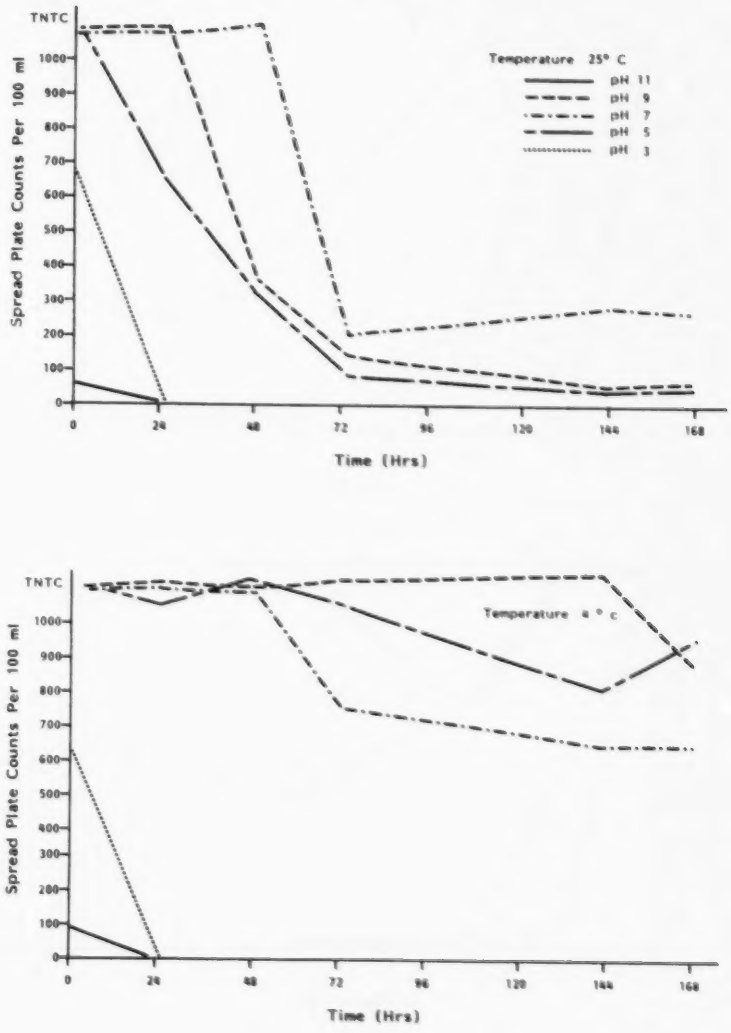
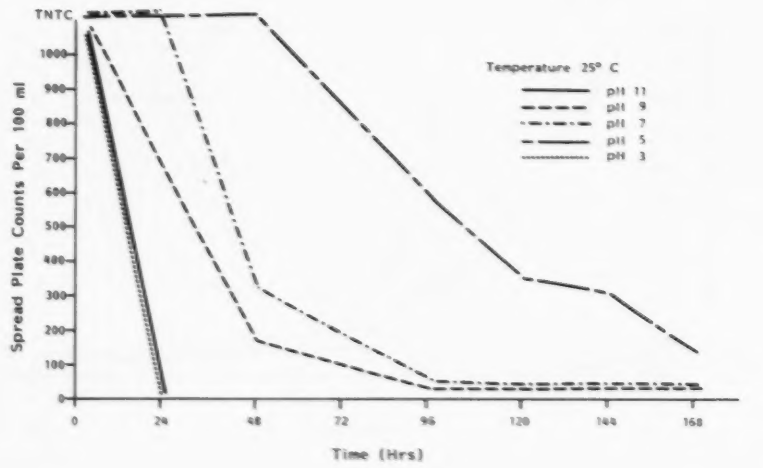


FIGURE 4 *Effect of Temperature and pH on S. typhimurium in Buffered Distilled Water*



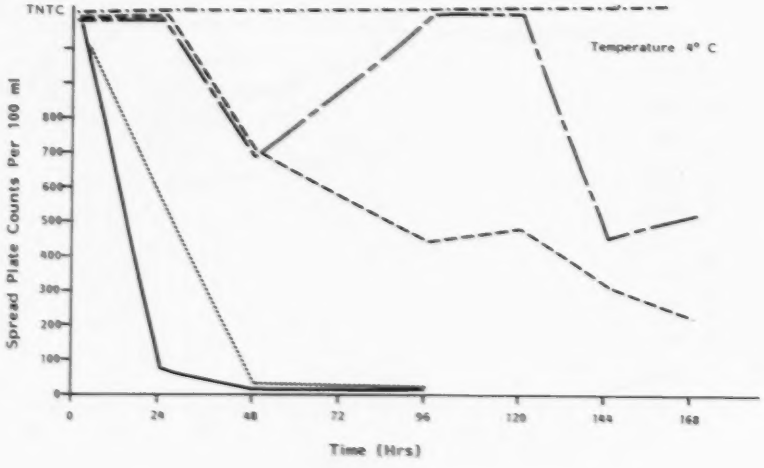
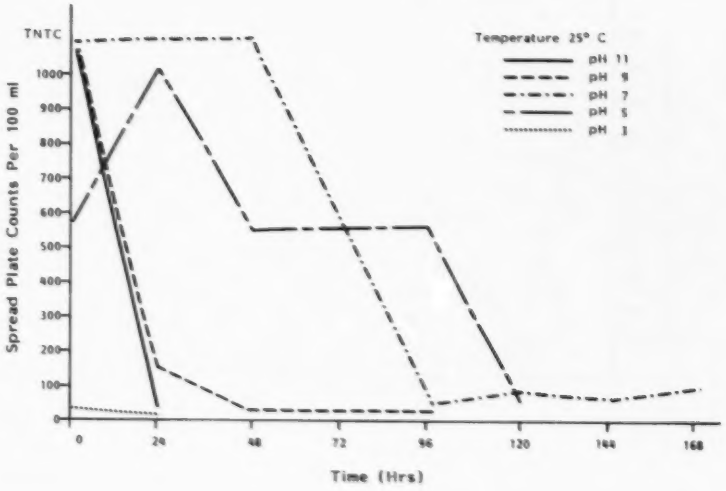


FIGURE 5 *Effect of Temperature and pH on S. typhimurium in Buffered Pond Water*



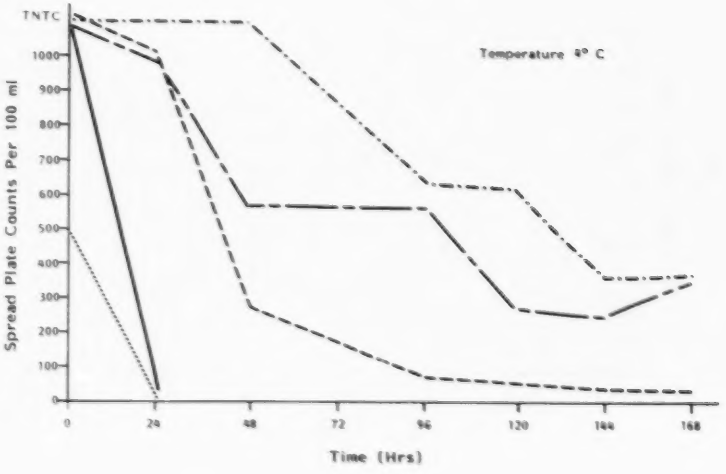


FIGURE 6 *Effect of Temperature and pH on S. typhimurium in Buffered Salt Water*

Official testing of environmental speciments by the GF/F filtration/elution MPN technique began in mid-March. Between that date and mid-October a total of 298 specimens had been logged. (Table 1). Six of the numbers were given to previously received environmental samples that were subsequently seeded with *S. typhimurium* to confirm that the techniques performed satisfactorily, making the actual number of samples examined 292. Twenty two of that total were from different sewage treatment facilities, with 16 (72.7%) specimens yielding *Salmonella* sp. Two hundred seventy samples were from environmental sites, almost all collected in replicate, with 21 (7.8%) of them yielding *Salmonella* sp.

The data on samples positive for Salmonella is presented in Table 2. In addition to site and date of collection, quantitative MPN/100 ml values and serogroups are given, as are total and fecal coliform and fecal strep MPN determinations. While several environmental sites have had more than one sample positive, only Tackapausha Pond, Carls River and Awixia Creek have yielded quantitatve Salmonella results on replicate samples collected on the same day. To date, five Salmonella serogroups have been isolated; B, C1, C2, D, and E, with B the most common (23). Thirteen of the samples have had two or more serogroups present. A library of Salmonella isolates has been kept for future speciation. There is a sharp quantitative difference between the environmental and STP samples, with Samonella MPN's on the former ranging from .03 to 1.2 while the latter are between 3.6 and 23/100 ml. In all samples with positive Salmonella findings there were parallel findings of elevated total and fecal coliform and fecal streptococcus MPN's. These assays ranged from 43 (TC), 23 (FC), 23 (FS)/100 ml in Unqua Pond to greater than 2,400,000/100 ml for each assay in several of the STP samples.

Preparations have been made for conducting Salmonella testing on storm runoff samples in parallel with samples for other environmental mirobiology and chemistry parameters. Salmonella sampling will begin at the earliest time that correlates with routine storm event sampling.

The 1979 *Centers for Disease Control Salmonella Surveillance* report indicates that since 1976 there has been an upward trend in human Salmonella isolations, along with a continued seasonal pattern with the greatest number of infections occurring in the May to October period and the fewest in the January to March period. With this peak seasonal incidence in mind, we are attempting to sample a variety of environmental sites on a regular basis to determine if frequency of isolation or quantitative difference become apparent. So far 15 environmental sites have been sampled along with 5 treatment plant locations, all within Nassau County. We plan to extend this survey to include sites in Suffolk County as well.

Table 1

ENVIRONMENTAL SAMPLES
FOR SALMONELLA AND INDICATOR BACTERIA ANALYSIS
MARCH-OCTOBER, 1982

Date	Sample Point Name	Lab. No.	Salmonella MPN/100 ml	Total Coliforms MPN/100 ml	Fecal Coliforms MPN/100 ml	Fecal Streptococcus MPN/100 ml
3-16-82	Roslyn Duck Pond	01	0/100 ml	ND*	ND	ND
3-16-82	Oyster Bay STP Inf.	02	0	ND	ND	ND
3-16-82	Oyster Bay STP Eff.	03	0	ND	ND	ND
3-22-82	Milburn Pond (Freeport Pond)	06	0	ND	ND	ND
3-22-82	Milburn Pond (Freeport Pond)	07	0.32	ND	ND	ND
3-31-82	Milburn Pond (Freeport Pond)	012 013	0.62 1.22	ND	ND	ND
4-14-82	Unqua Pond Inf.	014	0.09	43	23	240
4-14-82	Unqua Pond Inf.	015	0	240	43	240
4-14-82	Unqua Pond Inf.	016	0	43	43	240
4-14-82	Unqua Pond Eff.	017	0	930	240	21
4-14-82	Unqua Pond Eff.	018	0	93	93	3.6
4-14-82	Unqua Pond Eff.	019	0	240	240	23
4-28-82	Leed's Pond Eff.	020	0.09	240,000	24,000	9,300
4-28-82	Leed's Pond Eff.	021	0	240,000	93,000	24,000
4-28-82	E. Meadow Brook (W. Pond Spillway)	022	0	75,000	4,300	24,000
4-28-82	E. Meadow Brook (W. Pond Spillway)	023	0	240,000	4,300	110,000
4-28-82	Whitney Pond	024	0	110,000	9,300	> 240,000
4-28-82	Whitney Pond	025	0	46,000	9,300	21,000
5-6-82	Hall's Pond (Echo Pond)	026	0	2,400	39	240
5-6-82	Hall's Pond (Echo Pond)	027	0	240	23	> 3.0
5-6-82	Silver Lake Pond	028	0	240	240	240
5-6-82	Milburn Pond (Freeport Pond)	029	0	2,400	93	43

*ND–Not Determined

Table 1 (Continued)

Date	Sample Point Name	Lab. No.	Salmonella MPN/100 ml	Total Coliforms MPN/100 ml	Fecal Coliforms MPN/100 ml	Fecal Streptococcus MPN/100 ml
5-25-82	Dosoris Pond Eff.	30	0	< 3.0	< 3.0	< 3.0
5-25-82	Dosoris Pond Eff.	31	0	< 3.0	< 3.0	< 3.0
5-25-82	Cedar Swamp Creek	32	0	2,400	430	2,400
5-25-82	Cedar Swamp Creek	33	0	2,400	430	2,400
5-25-82	Roslyn Duck Pond	34	0	240	240	23
5-25-82	Roslyn Duck Pond	35	0	240	240	23
5-27-82	Unqua Pond Eff.	36	0	240	93	3.6
5-27-82	Unqua Pond Eff.	37	0	240	93	3.0
5-27-82	Seaford Pond	38	0	240	240	3.0
5-27-82	Seaford Pond	39	0	240	240	3.0
5-27-82	Milburn Pond	40	0	240	29	23
5-27-82	Milburn Pond	41	0	240	29	23
6-01-82	Dosoris Pond	42	0	< 3.0	< 3.0	23
6-01-82	Dosoris Pond	43	0	3.6	< 3.0	< 3.0
6-01-82	Cedar Swamp Creek	44	0	ND	ND	ND
6-01-82	Cedar Swamp Creek	45	0	2,400	240	75
6-01-82	Roslyn Duck Pond	46	0	ND	ND	ND
6-01-82	Roslyn Duck Pond	47	0	2,400	240	43
6-02-82	Glen Cove STP	48	0	> 2,400,000	> 2,400,000	> 2,400,000
6-02-82	Glen Cove STP	49	3.6	> 2,400,000	> 2,400,000	> 2,400,000
6-02-82	Port Washington STP	50	9.1	240,000	240,000	240,000
6-02-82	Port Washington STP	51	23	> 2,400,000	28,000	2,400
	Leeds Pond	52	0.23	4,300	1,500	430
6-02-82	Leeds Pond	53	0	4,300	4,300	930
6-02-82	Bay Park WPCF	54	11	> 2,400,000	> 2,400,000	> 2,400,000
6-02-82	Bay Park WPCF	55	9.1	> 2,400,000	> 2,400,000	> 2,400,000
6-02-82	Cedar Creek WPCF	56	0	240,000	930	240
6-02-82	Cedar Creek WPCF	57	0	2,400	35	2,400
6-07-82	Glen Cove Ced. Sw.	58	0.036	15,000	3,900	43,000
6-07-82	Cedar Swamp Creek	59	0	150,000	9,300	24,000
6-07-82	Roslyn Duck Pond	60	0	24,000	1,500	2,400
6-07-82	Roslyn Duck Pond	61	0	930	930	2,400
6-07-82	Leeds Pond	62	0	93,000	7,500	24,000
6-07-82	Leeds Pond	63	0	9,300	53	9,300
6-09-82	Tackapausha Pond	64	0.036	ND	ND	ND
6-09-82	Tackapausha Pond	65	0.036	ND	ND	ND
6-09-82	Milburn Pond	66	0	ND	ND	ND
6-09-82	Milburn Pond	67	0	ND	ND	ND
6-09-82	Unqua Pond	68	0	ND	ND	ND
6-09-82	Unqua Pond	69	0	ND	ND	ND
6-09-82	Smith Pond (Freeport)	70	0	ND	ND	ND
6-09-82	Smith Pond (Freeport)	71	0	ND	ND	ND
6-15-82	Milburn Pond	72	0	430	150	930
6-15-82	Milburn Pond	73	0	240	240	430
6-15-82	E. Meadow Brook (West Pond)	74	0	24,000	430	240
6-15-82	E. Meadow Brook (West Pond)	75	0	< 3.0	< 3.0	< 3.0
6-15-82	Cammann's Pond (Merrick)	76	0	150	39	< 3.0
6-15-82	Cammann's Pond (Merrick)	77	0	750	9.1	< 3.0
6-15-82	Tackapausha Pond	78	0	9,300	930	930
6-15-82	Tackapausha Pond	79	0	< 3.0	< 3.0	< 3.0
6-15-82	Unqua Pond	80	0.073	24,000	930	23
6-15-82	Unqua Pond	81	0	< 3.0	< 3.0	< 3.0
6-15-82	Cedar Swamp Creek	82	0	4,300	430	4,300
6-15-82	Cedar Swamp Creek	83	0	9,300	9,300	9,300
6-15-82	Powerhouse Drain	84	0	240,000	930	9,300
6-15-82	Powerhouse Drain	85	0	1,100,000	930	2,400
6-16-82	Roslyn Park Pond	86	0	2,400	93	240
6-16-82	Roslyn Park Pond	87	0	1,500	43	210
6-16-82	Leeds Pond Plandome	88	0	11	< 3.0	< 3.0
6-16-82	Leeds Pond Plandome	89	0	430	< 3.0	< 3.0
6-22-82	Unqua Pond	90	0	240	93	9.1
6-22-82	Unqua Pond	91	0	430	93	93
6-22-82	Tackapausha Pond	92	0	43,000	43,000	240
6-22-82	Tackapausha Pond	93	0	15,000	15,000	2,400
6-22-82	E. Meadow Brook (West Pond)	94	0	2,400	2,400	430
6-22-82	E. Meadow Brook (West Pond)	95	0	430	430	240
6-22-82	Milburn Pond	96	0	930	75	23
6-22-82	Milburn Pond	97	0	430	430	93
6-24-82	Cedar Swamp Creek	98	0	4,300	430	930
6-24-82	Cedar Swamp Creek	99	0	2,400	2,400	2,400
6-24-82	Powerhouse Drain	100	0	15,000	9,300	4,300
6-24-82	Powerhouse Drain	101	0	2,900	930	2,400
6-24-82	Roslyn Duck Pond	102	0	2,400	2,400	430
6-24-82	Roslyn Duck Pond	103	0	2,400	240	23

Table 1 (Continued)

Date	Sample Point Name	Lab. No.	Salmonella MPN/100 ml	Total Coliforms MPN/100 ml	Fecal Coliforms MPN/100 ml	Fecal Streptococcus MPN/100 ml
6-28-82	Beaver Lake	104	0	23	23	93
6-28-82	Beaver Lake	105	0	240	43	93
6-28-82	Cedar Swamp Creek	106	0	4,300	2,400	1,500
6-28-82	Cedar Swamp Creek	107	0	24,000	2,400	430
6-28-82	Powerhouse Drain	108	0	9,300	930	2,400
6-28-82	Powerhouse Drain	109	0	4,300	930	430
6-28-82	Roslyn Duck Pond	110	0	75	39	240
6-28-82	Roslyn Duck Pond	111	0	2,400	2,400	430
6-28-82	Leeds Pond	112	0	23	9.1	240
6-28-82	Leeds Pond	113	0	23	2,400	240
6-30-82	Unqua Pond	114	0	9,300	2,400	240
6-30-82	Unqua Pond	115	0	4,300	240	240
6-30-82	Tackapausha Pond	116	0	2,400,000	43,000	4,300
6-30-82	Tackapausha Pond	117	0	2,400,000	24,000	43,000
6-30-82	E. Meadow Brook (West Pond)	118	0	21,000	43	75
6-30-82	E. Meadow Brook (West Pond)	119	0	7,500	93	2,400
6-30-82	Milburn Pond	120	0	43,000	2,000	930
6-30-82	Milburn Pond	121	0.036	43,000	930	2,400
7-07-82	Beaver Lake	122	0	9.1	9.1	23
7-07-82	Beaver Lake	123	0	23	23	9.1
7-07-82	Cedar Swamp Creek	124	0	43,000	43,000	1,500
7-07-82	Cedar Swamp Creek	125	0	24,000	240	2,400
7-07-82	Powerhouse Drain	126	0	4,30	4,300	2,400
7-07-82	Powerhouse Drain	127	0	15,000	15,000	750
7-07-82	Roslyn Pond	128	0	930	930	240
7-07-82	Roslyn Pond	129	0	2,400	2,400	240
7-07-82	Leeds Pond	130	0	240	3.0	240
7-07-82	Leeds Pond	131	0	3.0	3.0	4,300
7-08-82	Jones' Beach Cent M.	132	0	2.0	NA	NA
7-08-82	Unqua Pond	133	0	430	150	23
7-13-82	Unqua Pond	134	0	930	430	9.1
7-13-82	Tackapausha Pond	135	0	930	44	240
7-13-82	Tackapausha Pond	136	0	2,400	44	240
7-13-82	Camman's Pond	137	0	390	140	240
7-13-82	Camman's Pond	138	0	390	93	430
7-13-82	Milburn Pond	139	0	2,400	430	240
7-13-82	Milburn Pond	140	0	640	240	240
7-15-82	Beaver Lake	141	0	3.0	3.0	9.1
7-15-82	Beaver Lake	142	0	3.0	3.0	3.0
7-15-82	Cedar Swamp Creek	143	0	2,400	2,400	2,400
7-15-82	Cedar Swamp Creek	144	0	2,400	2,400	240
7-15-82	Powerhouse Drain	145	0	43,000	24,000	2,400
7-15-82	Powerhouse Drain	146	0	2,400	2,400	240
7-15-82	Roslyn Park Pond	147	0	2,400	2,400	430
7-15-82	Roslyn Park Pond	148	0	2,400	2,400	240
7-15-82	Leeds Pond	149	0	3.0	3.0	240
7-15-82	Leeds Pond	150	0	240	240	930
7-15-82	Beaver Lake	151	0	240	240	240
7-20-82	Beaver Lake	152	0	430	240	43
7-20-82	Beaver Lake Sediment	153	0	ND	ND	ND
7-20-82	Cedar Swamp Creek	154	0	23	23	23
7-20-82	Cedar Swamp Creek	155	0	24,000	1,600	2,400
7-20-82	Powerhouse Drain	156	0	43	9.1	43
7-20-82	Powerhouse Drain	157	0	93	9.1	240
7-20-82	Roslyn Park Pond	158	0	430	430	430
7-20-82	Roslyn Park Pond	159	0	2,400	39	750
7-20-82	Roslyn Park Pond	160	0	ND	ND	ND
7-20-82	E. Meadow Brook	161	0	390	240	240
7-20-82	E. Meadow Brook	162	0.036	430	240	4,300
7-20-82	Jackson St. Storm Dr.	163	0	240	240	4,300
7-20-82	Jackson St. Storm Dr.	164	0.030	24,000	24,000	430
7-27-82	Unqua Pond	165	0	93	43	43
7-27-82	Unqua Pond	166	0	150	150	23
7-27-82	Unqua Pond	167	0	ND	ND	ND
7-27-82	Tackapausha Pond	168	0	24,000	1,500	2,400
7-27-82	Tackapausha Pond	169	0	4,300	1,500	430
7-27-82	Tackapausha Pond Sediment	170	0	ND	ND	ND
7-27-82	Tackapausha Pond	171	0	ND	ND	ND
7-27-82	Milburn Pond	172	0	430	240	240
7-27-82	Milburn Pond	173	0	ND	ND	ND
7-27-82	Milburn Pond	174	0	ND	ND	ND
7-28-82	Unqua Pond	175	0	24,000	930	43,000
7-28-82	Unqua Pond	176	0.061	24,000	4,300	43,000
7-28-82	Unqua Pond	177	0	24,000	2,400	24,000
7-28-82	Unqua Pond	178	0.035	2,400,000	28,000	2,400,000
7-28-82	Unqua Pond	179	0	43,000	24,000	24,000
7-28-82	Unqua Pond	180	0	24,000	9,300	93,000
7-28-82	Unqua Pond	181	0	43,000	430	93,000
7-28-82	Unqua Pond	182	0	240,000	240,000	460,000

Table 1 (Continued)

Date	Sample Point Name	Lab. No.	Salmonella MPN/100 ml	Total Coliforms MPN/100 ml	Fecal Coliforms MPN/100 ml	Fecal Streptococcus MPN/100 ml
7-28-82	Unqua Pond	183	0	1,100,000	720	1,100,000
7-28-82	Unqua Pond	184	0	43,000	4,300	75,000
8-02-82	04-093 Baldwin Harbor	185	0	23	23	ND
8-02-82	04-403 Adjacent to Oceanside Landfill	186	0	43	7.3	ND
8-02-82	03-4080 Reynold's Channel Near LB STP	187	0	43	3.6	ND
8-02-82	Bay Park STP-Outfall	188	0	ND	ND	ND
8-05-82	Beaver Lake	189	0	93	43	240
8-05-82	Beaver Lake	190	0	430	93	930
9-29-82	Carll's River	259	0.091	430	430	2,400
9-29-82	Carll's River	260	0	4,30	4,300	930
9-29-82	Santapogue Creek	261	0	4,300	4,300	930
9-29-82	Santapogue Creek	262	0	4,300	4,300	430
9-30-82	Milburn Pond	263	0	930	930	930
9-30-82	Milburn Pond	264	0	2,400	2,400	43
9-30-82	E. Meadow Brook West Pond	265	0	240	240	240
9-30-82	E. Meadow Brook West Pond	266	0	240	240	43
9-30-82	Tackapausha Pond	267	0	9,300	9,300	2,400
9-30-82	Tackapausha Pond	268	0	15,000	15,000	9,300
9-30-82	Unqua Pond	269	0	2,400	2,40	2,400
9-30-82	Unqua Pond	270	0	930	930	240
10-07-82	Beaver Lake	271	0	9.1	9.1	23
10-07-82	Beaver Lake	272	0	93	< 3.0	240
10-07-82	Cedar Swamp Creek	273	0	24,000	9,300	2,400
10-07-82	Cedar Swamp Creek	274	0	43,000	15,000	24,000
10-07-82	Powerhouse Drain	275	0	430	430	23
10-07-82	Powerhouse Drain	276	0	93	< 3.0	23
10-07-82	Roslyn Duck Pond	277	0	430	430	2,400
10-07-82	Leed's Pond	279	0	4,300	< 3.0	24,000
10-07-82	Leed's Pond	280	0	4,300	93	4,300
10-13-82	Forge River	281	0	240	240	43
10-13-82	Forge River	282	0	430	430	430
10-13-82	Carmans River	283	0	930	430	2,400
10-13-82	Carmans River	284	0	430	430	2,400
10-13-82	Awixla Creek	285	0	39,000	2,400	24,000
10-13-82	Awixla Creek	286	0	93,000	1,500	2,400
10-13-82	Carlls River	287	0	2,400	2,400	930
10-13-82	Carlls River	288	0	4,300	4,300	930
10-13-82	Santapogue Creek	289	0	930	930	240
10-13-82	Santapogue Creek	290	0	930	930	430
10-14-82	Unqua Pond Inf.	291	0	2,400	2,400	2,400
10-14-82	Unqua Pond Inf.	292	0	2,400	2,400	15,000
10-14-82	Unqua Pond Eff.	293	0	930	< 3.0	430
10-14-82	Unqua Pond Eff.	294	0	240	23	240
10-14-82	Tackapausha Pond	295	0	43,000	43,000	93,000
10-14-82	Tackapausha Pond	296	0	150,000	75	24,000
10-14-82	Milburn Pond	297	0	4,300	< 3.0	240
10-14-82	Milburn Pond	298	0	4,300	23	9,300
8-01-82	Leeds Pond	213	0	930	43	1,200
8-01-82	Leeds Pond	214	0	2,400	2,400	930
8-01-82	Roslyn Duck Pond	215	0	2,400	430	930
8-01-82	Roslyn Duck Pond	216	0	430	430	2,400
9-01-82	Cedar Swamp Creek	217	0	1,500	930	1,400
9-01-82	Cedar Swamp Creek	218	0	2,400	2,400	2,400
9-01-82	Beaver Lake	219	0	23	23	43
9-01-82	Beaver Lake	220	0	2,400	3.6	240
9-01-82	Powerhouse Drain	221	0	24,000	240	2,400
9-01-82	Powerhouse Drain	222	0	9,300	930	440
9-09-82	E. Meadow Brook West Pond	223	0	430	240	43
9-09-82	E. Meadow Brook West Pond	224	0	2,400	23	750
9-09-82	Milburn Pond	225	0	3,900	2,400	750
9-09-82	Milburn Pond	226	0	9,300	430	930
9-09-82	Tackapausha Pond	227	0	7,500	430	1,400
9-09-82	Tackapausha Pond	228	0	2,400	2,400	430
9-09-82	Unqua Pond	229	0	390	390	93
9-09-82	Unqua Pond	230	0	240	240	140
9-14-82	Cedar Creek WPCF Inf.	231	23	> 2,400,000	> 2,400,000	> 2,400,000
9-14-82	Cedar Creek WPCF Inf.	232	7.2	> 2,400,000	> 2,400,000	> 2,400,000
9-14-82	Cedar Creek WPCF Eff.	233	6.1	> 2,400,000	> 2,400,000	> 2,400,000
9-14-82	Cedar Creek WPCF Eff.	234	0	> 2,400,000	> 2,400,000	> 2,400,000
9-14-82	Cedar Creek WPCF Slud.	235	9.1	ND	ND	ND

Table 2

POSITIVE SALMONELLA SAMPLES

Sample No.	Date of Collection	Source	Salmonella MPN/100 ml	Sero Group	Total Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Strep MPN/100 ml
07	3-22-82	Freeport Duck Pond (Milburn)	0.32	B	ND	ND	ND
12	3-22-82	Freeport Duck Pond (Milburn)	1.22	B	ND	ND	ND
13	3-31-82	Freeport Duck Pond (Milburn)	0.62	B	ND	ND	ND
14	4-14-82	Unqua Pond	0.09	B	43*	23	240
20	4-28-82	Leeds Pond	0.09	C2	240,000	240,000	9,300
49	6-2-82	Glen Cove STP	3.6	C2	>2,400,000	>2,400,000	>2,400,000
50	6-2-82	Port Washington STP	9.1-23	B,C2	240,000	240,000	240,000
51	6-2-82	Port Washington STP	23	B,C2	>2,400,000	28,000	2,400
52	6-2-82	Leeds Pond	0.03	B,C2	4,300	1,500	430
54	6-2-82	Bay Park WPCF	11	B,E	>2,400,000	>2,400,000	>2,400,000
55	6-2-82	Bay Park WPCF	9.1	E	>2,400,000	>2,400,000	>2,400,000
58	6-9-82	Cedar Swamp Creek	0.036	B	15,000	3,900	43,000
64	6-9-82	Tackapausha Pond	0.036	B,E	ND**	ND	ND
65	6-9-82	Tackapausha Pond	0.036	E	ND**	ND	ND
80	6-15-82	Unqua Pond	0.073	C2	24,000	930	23
121	6-30-82	Milburn Pond	0.036	C2	43,000	930	2,400
162	7-20-82	E. Meadow Brook	0.036	B	430	240	4,300
164	7-20-82	Jackson St. Storm Drain	0.030	B	24,000	24,000	430
176	7-28-82	Unqua Pond STM EVT	0.061	C2	24,000	4,300	43,000
178	7-28-82	Unqua Pond STM EVT	0.036	C2	>2,400,000	28,000	>2,400,000
209	9-01-82	Carlls River Suffolk	0.030	C2	4,300	4,300	2,400
210	9-01-82	Carrls River Suffolk	0.036	B	9,300	240	2,400

Table 2 (Continued)

Sample No.	Date of Collection	Source	Salmonella MPN/100 ml	Sero Group	Total Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Strep MPN/100 ml
231	9-14-82	Cedar Creek WPCF Inf.	23	B,C1 C2,D	> 2,400,000	> 2,400,000	> 2,400,000
232	9-14-82	Cedar Creek WPCF Inf.	7.2	D	> 2,400,000	> 2,400,000	> 2,400,000
233	9-14-82	Cedar Creek WPCF Eff.	6.1	C1,E	> 2,400,000	> 2,400,000	> 2,400,000
235	9-14-82	Cedar Creek Sludge	9.1	B,C1, D	ND	ND	ND
236	9-14-82	Cedar Creek Sludge	23	D	ND	ND	ND
237	9-14-82	Bay Park WPCF Inf.	23	C2,D	> 2,400,000	> 2,400,000	> 2,400,000
238	9-14-82	Bay Park WPCF Inf.	39	D	> 2,400,000	> 2,400,000	> 2,400,000
239	9-14-82	Bay Park WPCF Eff.	9.3	B,C1, D	> 2,400,000	> 2,400,000	> 2,400,000
240	9-14-82	Bay Park WPCF Eff.	240	B,C1 C2,E	> 2,400,000	> 2,400,000	> 2,400,000
241	9-14-82	Bay Park WPCF Sludge	15	B,C1	ND	ND	ND
242	9-14-82	Bay Park WPCF Sludge	15	B,C1, D	ND	ND	ND
250	9-14-82	Carlls River Suffolk	0.15	B	2,400	2,400	4,300
257	9-29-82	Awixla Creek Suffolk	0.036	B	9,300	1,500	2,400
258	9-29-82	Awixla Creek Suffolk	0.036	B	9,300	1,500	2,400
259	9-29-82	Carlls River Suffolk	0.091	B	430	430	2,400

Routine assay begun

**Specimen sterilized before assay could be performed